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Wool Fiberglass Insulation Manufacturing Industry - Background Information for Proposed Standards

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Research Triangle Park, NC

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16. ABSTRACT

A Standard of Performance for the control of emissions from wool fiberglass insulation manufacturing facilities is being proposed under authority of Section 111 of the Clean Air Act. This standard would apply to new, modified, or reconstructed wool fiberglass insulation manufacturing lines that utilize the rotary spin forming process and that commence construction on or after the date of proposal of the regulation. This document contains background information and environmental and economic impact assessments of the regulatory alternatives considered in developing the proposed standard.

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Wool Fiberglass Insulation Manufacturing Industry -

Background Information for Proposed Standards

Emission Standards and Engineering Division

U.S ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

December 1983

i.a

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ENVIRONMENTAL PROTECTION AGENCY

Background Information
and Draft
Environmental Impact Statement
for the Wool Fiberglass Insulation Manufacturing Industry

Prepared by:

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1. The proposed standard of performance would limit emissions of particulate matter from new, modified, and reconstructed wool fiberglass insulation manufacturing lines that utilize the rotary spin forming process. Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended, directs the Administrator to establish standards of performance for any category of new stationary source of air pollution that ". . . causes or contributes significantly to air pollution which may reasonably be anticipated to endanger public health or welfare."

2. Copies of this document have been sent to the following Federal Departments: Labor, Health and Human Services, Defense, Transportation, Agriculture, Commerce, Interior, and Energy; the National Science Foundation; the Council on Environmental Quality; State and Territorial Air Pollution Program Administrators; EPA Regional Administrators; Local Air Pollution Control Officials; Office of Management and Budget; and other interested parties.

3. The comment period for review of this document is 60 days. Mr. Robert L. Ajax may be contacted regarding the date of the comment period.

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1. SUMMARY

1.1 REGULATORY ALTERNATIVES

Standards of performance for new stationary sources are developed under Section 111 of the Clean Air Act (42 U.S.C. 7411), as amended. Section 111 requires the establishment of standards of performance for any new stationary source which ". . . causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." The Act requires standards of performance for such sources to ". . . reflect the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction which (taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact, and energy requirements) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction, modification, or reconstruction of which starts after regulations are proposed in the Federal Register.

Regulatory alternatives were considered for wool fiberglass insulation lines utilizing the rotary spin (RS) and the flame attenuation (FA) forming processes. These alternatives are presented in Chapter 6. For RS lines, Regulatory Alternative 1 would require no additional Federal regulatory action. Under this alternative, emissions from forming and curing are controlled to comply with State regulations, and cooling emissions are uncontrolled. This alternative is considered to be the baseline condition against which the impacts of the other alternatives are compared. Regulatory Alternative II represents additional control of forming emissions over baseline, Alternative III represents additional control of forming and curing emissions, and Alternative IV represents additional control of forming, curing, and cooling emissions.

For FA lines, Regulatory Alternative I (baseline) represents no control of forming, curing, or cooling emissions. Regulatory Alternatives II, III, and IV represent control of curing emissions, curing and cooling emissions, and forming emissions, respectively. No growth is projected for the FA segment of the industry. Therefore, no environmental or economic impacts for the fifth year after proposal were calculated for the FA regulatory alternatives.

1.2 ENVIRONMENTAL IMPACT

The beneficial and adverse environmental impacts associated with each RS regulatory alternative are compared with the baseline in Tables 1-1 and 1-2. The impacts for Alternatives II, III, and IV are based on the wet ESP control option in each case. Standards of performance based on either Alternatives II, III, or IV will result in a small-to-large beneficial impact on air quality. No impact on water quality or noise levels will result from any of the alternatives. A moderate-to-large adverse impact on solid waste generation will result from adoption of Alternatives II, III, and IV. Energy requirements will increase slightly over baseline levels under Alternative II and will decrease significantly under Alternatives III and IV. A detailed analysis of the environmental impacts is presented in Chapter 7.

1.3 ECONOMIC IMPACT

The economic impacts of each regulatory alternative are presented in Tables 1-1 and 1-2. For Alternatives II, III, or IV, capital costs for industry compliance with the proposed standard over the first 5 years will increase by 5 to 7 percent over baseline capital expenditures. Fifth-year annualized costs for industry compliance will increase only slightly over baseline.

The economic analysis indicates that the proposed standard could increase the price of wool fiberglass insulation approximately 1 percent. This could increase the estimated cost to insulate a 139 m^2 (1,500 ft^2) house from $1,496 to $1,510, an increase of $14. The costs of emission control equipment required by the alternatives are expected to have only

TABLE 1-1. ENVIRONMENTAL AND ECONOMIC IMPACTS OF VARIOUS ALTERNATIVES COMPARED TO ALTERNATIVE I (BASELINE) IN THE FIFTH YEAR

Reg. alt.	Emission reduction			Solid waste increase			Energy increase/decrease[a]			Cost increase			
	Mg/yr	tons/yr	Percent	Mg/yr	tons/yr	Percent	TJ/yr	10^9 Btu/yr	Per-cent	Capital, $	Percent	Annualized, $	Per-cent
II	9,440	10,400	66	9,400	10,400	80	+120	+114	+8	36,114,000	6	10,721,000	1.3
III	11,450	12,630	81	11,450	12,630	97	-1,280	-1,220	-81	41,443,000	7	3,148,000	0.4
IV	11,590	12,780	82	11,590	12,780	98	-1,260	-12,00	-79	44,533,000	7	41,154,000	0.5

[a] Energy increase/decrease refers to total energy demand (electricity and natural gas) for each regulatory alternative.

TABLE 1-2. MATRIX OF ENVIRONMENTAL AND ECONOMIC IMPACTS FOR REGULATORY ALTERNATIVES

Regulatory alternative	Air impact	Water impact	Solid waste impact	Energy impact	Noise impact	Economic impact
I	0	0	0	0	0	0
II	+3**	0	-3**	-1***	0	-1**
III	+4**	0	-4**	+4***	0	-1**
IV	+4**	0	-4**	+4***	0	-1**

Key:
+ = Beneficial impact.
- = Adverse impact.
* = Short-term impact.
** = Long-term impact.
*** = Irreversible impact.

0 = No impact.
1 = Negligible impact.
2 = Small impact.
3 = Moderate impact.
4 = Large impact.

a negligible adverse impact on the wool fiberglass insulation manufacturing industry. Detailed analyses of the costs and the economic impacts are presented in Chapters 8 and 9.

2. INTRODUCTION

2.1 BACKGROUND AND AUTHORITY FOR STANDARDS

Before standards of performance are proposed as a Federal regulation, air pollution control methods available to the affected industry and the associated costs of installing and maintaining the control equipment are examined in detail. Various levels of control based on different technologies and degrees of efficiency are expressed as regulatory alternatives. Each of these alternatives is studied by the EPA as a prospective basis for a standard. The alternatives are investigated in terms of their impacts on the economics and well-being of the industry, the impacts on the national economy, and the impacts on the environment. This document summarizes the information obtained through these studies so that interested persons will be able to see the information considered by the EPA in the development of the proposed standards.

Standards of performance for new stationary sources are established under Section 111 of the Clean Air Act (42 U.S.C. 7411) as amended, hereafter referred to as the Act. Section 111 directs the Administrator to establish standards of performance for any category of new stationary source of air pollution which ". . . causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare."

The Act requires that standards of performance for stationary sources reflect ". . . the degree of emission limitation and the percentage reduction achievable through application of the best technological system of continuous emission reduction which (taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact and energy requirements) the Administrator determines has been adequately demonstrated." The standards apply only to stationary sources, the construction or modification of which commences after the standards are proposed in the Federal Register.

The 1977 amendments to the Act altered or added numerous provisions that apply to the process of establishing standards of performance. Examples of the effects of the 1977 amendments are:

1. EPA is required to review the standards of performance every 4 years and, if appropriate, revise them.

2. EPA is authorized to promulgate a standard based on design, equipment, work practice, or operational procedures when a standard based on emission levels is not feasible.

3. The term "standards of performance" is redefined, and a new term "technological system of continuous emission reduction" is defined. The new definitions clarify that the control system must be continuous and may include a low- or non-polluting process or operation.

4. The time between the proposal and promulgation of a standard under Section 111 of the Act may be extended to 6 months.

Standards of performance, by themselves, do not guarantee protection of health or welfare because they are not designed to achieve any specific air quality levels. Rather, they are designed to reflect the degree of emission limitation achievable through application of the best adequately demonstrated technological system of continuous emission reduction, taking into consideration the cost of achieving such emission reduction, any nonair quality health and environmental impact and energy requirements.

Congress had several reasons for including these requirements. First, standards having a degree of uniformity are needed to avoid situations where some States may attract industries by relaxing standards relative to other States. Second, stringent standards enhance the potential for long-term growth. Third, stringent standards may help achieve long-term cost savings by avoiding the need for more expensive retrofitting when pollution ceilings may be reduced in the future. Fourth, certain types of standards for coal-burning sources can adversely affect the coal market by driving up the price of low-sulfur coal or by effectively excluding certain coals from the reserve base due to their high untreated pollution potentials. Congress does not intend that new source performance standards contribute to these problems. Fifth, the standard-setting process should create incentives for improving technology.

Promulgation of standards of performance does not prevent State or local agencies from adopting more stringent emission limitations for the same sources. States are free under Section 116 of the Act to establish even more stringent emission limits than those established under Section 111 or than those necessary to attain or maintain the National Ambient Air Quality Standards (NAAQS) under Section 110. Thus, new sources may in some cases be subject to State limitations that are more stringent than standards of performance under Section 111, and prospective owners and operators of new sources should be aware of this possibility in planning for such facilities.

A similar situation may arise when a major emitting facility is to be constructed in a geographic area that falls under the prevention of significant deterioration of air quality provisions of Part C of the Act. These provisions require, among other things, that major emitting facilities to be constructed in such areas are to be subject to best available control technology. The term "best available control technology" (BACT), as defined in the Act, means

> . . . an emission limitation based on the maximum degree of reduction of each pollutant subject to regulation under this Act emitted from or which results from any major emitting facility, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such facility through application of production processes and available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of each such pollutant. In no event shall application of "best available control technology" result in emissions of any pollutants which will exceed the emissions allowed by any applicable standard established pursuant to Sections 111 or 112 of this Act. (Section 169(3))

Although standards of performance are normally structured in terms of numerical emission limits where feasible, alternative approaches are sometimes necessary. In some cases, physical measurement of emissions from a new source may be impractical or exorbitantly expensive. Section 111(h) provides that the Administrator may promulgate a design or equipment standard in those cases where it is not feasible to prescribe or enforce a standard of performance. For example, emissions of hydrocarbons from storage vessels for petroleum liquids are greatest during tank filling. The nature of the emissions (i.e., high concentrations for short periods during filling and low concentrations for longer periods during storage) and the configuration of storage tanks make direct emission measurement impractical. Therefore, a more practical approach to standards of performance for storage vessels has been equipment specification.

In addition, under Section 111(j) the Administrator may, with the consent of the Governor of the State in which a source is to be located, grant a waiver of compliance to permit the source to use an innovative technological system or systems of continuous emission reduction. In order to grant the waiver, the Administrator must find that: (1) the proposed system has not been adequately demonstrated; (2) the proposed system will operate effectively and there is a substantial likelihood that the system will achieve greater emission reductions than the otherwise applicable standards require or at least an equivalent reduction at lower economic, energy, or nonair quality environmental cost; (3) the proposed system will not cause or contribute to an unreasonable risk to public health, welfare, or safety; and (4) the waiver when combined with other similar waivers, will not exceed the number necessary to achieve conditions (2) and (3) above. A waiver may have conditions attached to ensure the source will not prevent attainment of any NAAQS. Any such condition will be treated as a performance standard. Finally, waivers have definite end dates and may be terminated earlier if the conditions are not met or if the system fails to perform as expected. In such a case, the source may be given up to 3 years to meet the standards and a mandatory compliance schedule will be imposed.

2.2 SELECTION OF CATEGORIES OF STATIONARY SOURCES

Section 111 of the Act directs the Administrator to list categories of stationary sources. The Administrator ". . . shall include a category of sources in such list if in his judgment it causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health or welfare." Proposal and promulgation of standards of performance are to follow.

Since passage of the Clean Air Amendments of 1970, considerable attention has been given to the development of an approach for assigning priorities to various source categories. The approach specifies areas of interest by considering the broad strategy of the Agency for implementing the Clean Air Act. Often, these areas are pollutants that are emitted by stationary sources rather than the stationary sources themselves. Source categories that emit these pollutants were evaluated and ranked considering such factors as: (1) the level of emission control (if any) already required by State regulations; (2) estimated levels of control that might be required from standards of performance for the source category; (3) projections of growth and replacement of existing facilities for the source category; and (4) the estimated incremental amount of air pollution that could be prevented in a preselected future year by standards of performance for the source category. Sources for which new source performance standards were promulgated or under development during 1977, or earlier, were selected using these criteria.

The Act amendments of August 1977 establish specific criteria to be used in determining priorities for all source categories not yet listed by the EPA. These are: (1) the quantity of air pollutant emissions which each such category will emit, or will be designed to emit; (2) the extent to which each such pollutant may reasonably be anticipated to endanger public health or welfare; and (3) the mobility and competitive nature of each such category of sources and the consequent need for nationally applicable new source standards of performance.

The Administrator is to promulgate standards for these categories according to the schedule referred to earlier.

In some cases, it may not be immediately feasible to develop standards for a source category with a high priority. This might happen if a program of research is needed to develop control techniques or if techniques for sampling and measuring emissions require refinement. In the developing of standards, differences in the time required to complete the necessary investigation for different source categories must also be considered. For example, substantially more time may be necessary if numerous pollutants must be investigated from a single source category. Further, even late in the development process the schedule for completion of a standard may change. For example, inability to obtain emission data from well-controlled sources in time to pursue the development process in a systematic fashion may force a change in scheduling. Nevertheless, priority ranking is, and will continue to be, used to establish the order in which projects are initiated and resources assigned.

After the source category has been chosen, the types of facilities within the source category to which the standard will apply must be determined. A source category may have several facilities that cause air pollution, and emissions from these facilities may vary according to magnitude and control cost. Economic studies of the source category and of applicable control technology may show that air pollution control is better served by applying standards to the more severe pollution sources. For this reason, and because there is no adequately demonstrated system for controlling emissions from certain facilities, standards often do not apply to all facilities at a source. For the same reasons, the standards may not apply to all air pollutants emitted. Thus, although a source category may be selected to be covered by standards of performance, not all pollutants or facilities within that source category may be covered by the standards.

2.3 PROCEDURE FOR DEVELOPMENT OF STANDARDS OF PERFORMANCE

Standards of performance must: (1) realistically reflect best demonstrated control practice; (2) adequately consider the cost, the nonair quality health and environmental impacts, and the energy requirements of such control; (3) be applicable to existing sources that are modified or reconstructed as well as to new installations; and (4) meet these conditions for all variations of operating conditions being considered anywhere in the country.

The objective of a program for development of standards is to identify the best technological system of continuous emission reduction that has been adequately demonstrated. The standard-setting process involves three principal phases of activity: (1) information gathering;

(2) analysis of the information; and (3) development of the standard of performance.

During the information gathering phase, industries are questioned through telephone surveys, letters of inquiry, and plant visits by EPA representatives. Information is also gathered from other sources, including a literature search. Based on the information acquired about the industry, the EPA selects certain plants at which emission tests are conducted to provide reliable data that characterize the pollutant emissions from well-controlled existing facilities.

In the second phase of a project, the information about the industry and the pollutants emitted is used in analytical studies. Hypothetical "model plants" are defined to provide a common basis for analysis. The model plant definitions, national pollutant emission data, and existing State regulations governing emissions from the source category are then used in establishing "regulatory alternatives." These regulatory alternatives are essentially different levels of emission control.

The EPA conducts studies to determine the impact of each regulatory alternative on the economics of the industry and on the national economy, on the environment, and on energy consumption. From several alternatives, the EPA selects the single most plausible regulatory alternative as the basis for standards of performance for the source category under study.

In the third phase of a project, the selected regulatory alternative is translated into performance standards, which, in turn, are written in the form of a Federal regulation. The Federal regulation, when applied to newly constructed plants, will limit emissions to the levels indicated in the selected regulatory alternative.

As early as is practical in each standard-setting project, EPA representatives discuss the possibilities of a standard and the form it might take with members of the National Air Pollution Control Techniques Advisory Committee. Industry representatives and other interested parties also participate in these meetings.

The information acquired in the project is summarized in the background information document (BID). The BID, the proposed standard, and a preamble explaining the standard are widely circulated to the industry being considered for control, environmental groups, other government agencies, and offices within the EPA. Through this extensive review process, the points of view of expert reviewers are taken into consideration as changes are made to the documentation.

A "proposal package" is assembled and sent through the offices of EPA assistant administrators for concurrence before the proposed standard is officially endorsed by the EPA Administrator. After being approved by the EPA Administrator, the preamble and the proposed regulation are published in the Federal Register.

As part of the Federal Register announcement of the proposed regulation, the public is invited to participate in the standard-setting process. The EPA invites written comments on the proposal and also holds a public hearing to discuss the proposed standard with interested parties. All public comments are summarized and incorporated into a second volume of the BID. All information reviewed and generated in studies in support of the standard of performance is available to the public in a "docket" on file in Washington, D.C.

Comments from the public are evaluated, and the standard of performance may be altered in response to the comments.

The significant comments and the EPA's position on the issues raised are included in the "preamble" of a promulgation package, which also contains the draft of the final regulation. The regulation is then subjected to another round of review and refinement until it is approved by the EPA Administrator. After the Administrator signs the regulation, it is published as a "final rule" in the Federal Register.

2.4 CONSIDERATION OF COSTS

Section 317 of the Act requires an economic impact assessment with respect to any standard of performance established under Section 111 of the Act. The assessment is required to contain an analysis of: (1) the costs of compliance with the regulation, including the extent to which the cost of compliance varies depending on the effective date of the regulation and the development of less expensive or more efficient methods of compliance; (2) the potential inflationary and recessionary effects of the regulation; (3) the effects the regulation might have on small business with respect to competition; (4) the effects of the regulation on consumer costs; and (5) the effects of the regulation on energy use. Section 317 requires that the economic impact assessment be as extensive as practicable.

The economic impact of a proposed standard upon an industry is usually addressed both in absolute terms and by comparison with the control costs that would be incurred as a result of compliance with typical, existing State control regulations. An incremental approach is taken because both new and existing plants would be required to comply with State regulations in the absence of a Federal standard of performance. This approach requires a detailed analysis of the economic impact of the cost differential that would exist between a proposed standard of performance and the typical State standard.

Air pollutant emissions may cause water pollution problems, and captured potential air pollutants may pose a solid waste disposal problem. The total environmental impact of an emission source must, therefore, be analyzed and the costs determined whenever possible.

A thorough study of the profitability and price-setting mechanisms of the industry is essential to the analysis so that an accurate estimate of potential adverse economic impacts can be made for proposed standards. It is also essential to know the capital requirements for pollution control systems already placed on plants so that the additional capital requirements necessitated by these Federal standards can be placed in proper perspective. Finally, it is necessary to assess the availability of capital to provide the additional control equipment needed to meet the standards of performance.

2.5 CONSIDERATION OF ENVIRONMENTAL IMPACTS

Section 102(2)(C) of the National Environmental Policy Act (NEPA) of 1969 requires Federal agencies to prepare detailed environmental impact statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The objective of NEPA is to build into the decision-making process of Federal agencies a careful consideration of all environmental aspects of proposed actions.

In a number of legal challenges to standards of performances for various industries, the United States Court of Appeals for the District of Columbia Circuit has held that environmental impact statements need not be prepared by the Agency for proposed actions under Section 111 of the Clean Air Act. Essentially, the Court of Appeals has determined that the best system of emission reduction requires the Administrator to take into account counterproductive environmental effects of proposed standards, as well as economic costs to the industry. On this basis, therefore, the Courts established a narrow exemption from NEPA for EPA determinations under Section 111.

In addition to these judicial determinations, the Energy Supply and Environmental Coordination Act (ESECA) of 1974 (PL-93-319) specifically exempted proposed actions under the Clean Air Act from NEPA requirements. According to Section 7(c)(1), "No action taken under the Clean Air Act shall be deemed a major Federal action significantly affecting the quality of the human environment within the meaning of the National Environmental Policy Act of 1969." (15 U.S.C. 793(c)(1))

Nevertheless, the Agency has concluded that the preparation of environmental impact statements could have beneficial effects on certain regulatory actions. Consequently, although not legally required to do so by Section 102(2)(C) of NEPA, the EPA has adopted a policy requiring that environmental impact statements be prepared for various regulatory actions, including standards of performance developed under Section 111 of the Act. This voluntary preparation of environmental impact statements, however, in no way legally subjects the Agency to NEPA requirements.

To implement this policy, a separate section is included in this document which is devoted solely to an analysis of the potential environmental impacts associated with the proposed standards. Both adverse and beneficial impacts in such areas as air and water pollution, increased solid waste disposal, and increased energy consumption are discussed.

2.6 IMPACT ON EXISTING SOURCES

Section 111 of the Act defines a new source as ". . . any stationary source, the construction or modification of which is commenced . . ." after the proposed standards are published. An existing source is redefined as a new source if "modified" or "reconstructed" as defined in amendments to the General Provisions (40 CFR Part 60, Subpart A), which were promulgated in the Federal Register on December 16, 1975 (40 FR 58416).

Promulgation of standards of performance requires States to establish standards of performance for existing sources in the same industry under Section 111(d) of the Act if the standard for new sources limits emissions of a designated pollutant (i.e., a pollutant for which air quality criteria have not been issued under Section 108 or which has not been listed as a hazardous pollutant under Section 112). If a State does not act, the EPA must establish such standards. General procedures for control of existing sources under Section 111(d) were promulgated on November 17, 1975, as Subpart B of 40 CFR Part 60 (40 FR 53340).

2.7 REVISION OF STANDARDS OF PERFORMANCE

Congress was aware that the level of air pollution control achievable by any industry may improve with technological advances. Accordingly, Section 111 of the Act provides that the Administrator ". . . shall, at least every 4 years, review and, if appropriate, revise . . ." the standards. Revisions are made to ensure that the standards continue to reflect the best systems that become available in the future. Such revisions will not be retroactive but will apply to stationary sources constructed or modified after the proposal of the revised standards.

3. PROCESS DESCRIPTION

3.1 GENERAL

3.1.1 Industry Description

Wool fiberglass insulation manufacturing is a source category under the Standard Industrial Classification (SIC) Code 3296, "Mineral Wool."[1] In this process, molten glass is formed into fibers that are bonded with an organic resin, thus creating a wool-like material that is used as thermal or acoustical insulation.

Wool fiberglass insulation is produced by two processes: flame attenuation (FA) and rotary spin (RS). In the FA process, continuous threads of glass are formed as molten glass flows by gravity from a furnace. These threads are then attenuated (i.e., stretched to the point of breaking) with direct flames and high velocity air to form fibers. In the RS process, centrifugal force causes molten glass to pass through small orifices in a spinner to form fibers that are subsequently broken into pieces by jets of air. The FA process was the original method for forming fibers but contributed less than 20 percent to the total industry production in 1980.[2] The RS process was developed in the 1950's and dominates the industry today.

Wool fiberglass is currently produced in the United States by five companies. These companies operate 25 plants located in 11 States (Table 3-1). One company produces over 50 percent of all wool fiberglass insulation.[3]

Wool fiberglass is used for building (residential and nonresidential) insulation, pipe insulation, ventilation ducts, appliance and equipment insulation, automotive insulation, and acoustical ceiling insulation. Table 3-2 shows the market share of these products for 1980. The various

TABLE 3-1. LOCATION OF WOOL FIBERGLASS INSULATION MANUFACTURING PLANTS

State	Number of plants
California	4
Georgia	3
Indiana	2
Kansas	3
Michigan	1
New Jersey	3
New York	1
Ohio	4
Pennsylvania	1
Texas	2
West Virginia	1

TABLE 3-2. ESTIMATES OF THE DEMAND FOR WOOL FIBERGLASS INSULATION IN 1980 BY END USE[4]

End use	Demand		Percent of total demand
	10^5 Mg	10^5 tons	
Structural			
Residential			
New houses	3.20	3.53	27.2
Mobile homes	0.54	0.60	4.6
Retrofit	3.61	3.98	30.6
Total residential	7.35	8.11	62.4
Nonresidential[a]	1.98	2.18	16.8
Total structural	9.33	10.29	79.2
Nonstructural			
Pipe insulation	0.80	0.88	6.7
Air handling	0.59	0.65	5.0
Other	1.07	1.18	9.1
Total nonstructural	2.46	2.71	20.8
Total	11.79	13.00	100.00

[a] Includes nonresidential use of roof insulation.

products differ primarily in thickness, density, length, width, backing, fiber diameter, and the composition of the binder (organic compounds used to hold the fibers together). Table 3-3 presents ranges of values for fiber diameter, product density, and maximum temperature limits.

3.1.2 Industry Growth

Growth in wool fiberglass production from 1971 to 1980 is shown in Figure 3-1. Growth in the fiberglass insulation market was slow until the 1970's. Between 1971 and 1979, residential insulation demand increased as a result of the 1971 Federal Housing Administration minimum property standards, the fuel shortage of 1973 and 1974, and the 1977 Federal tax incentives. The wool fiberglass industry responded to the demand by increasing total insulation production from approximately 0.9 $\times 10^6$ megagrams per year (Mg/yr) (1.0 $\times 10^6$ tons per year [tons/yr]) in 1974 to 1.3 $\times 10^6$ Mg/yr (1.5 $\times 10^6$ tons/yr) in 1979.[5,6] However, the recent recession and poor economic conditions have caused insulation production to decrease to 1.2 $\times 10^6$ Mg/yr (1.4 $\times 10^6$ tons/yr) in 1980.[5]

Production capacities for wool fiberglass grew rapidly during the 1970's; new plants were built in California and Georgia, and lines were added to existing plants in Texas, New York, and Indiana. The utilization of production capacity in the wool fiberglass manufacturing industry in 1980 was estimated to be about 72 percent.[7] Economic conditions since 1980 have reduced demand for fiberglass and, thus, reduced utilization of fiberglass manufacturing capacity.

From 1964 to 1974, the average price of fiberglass ranged from 53 to 73 cents per kilogram (kg) (24 to 33 cents per pound [lb]).[5,8] The price in 1980 was \$1.19 per kg (\$0.54 per lb).[6]

In the residential building market, wool fiberglass insulation is used in new homes, retrofitting, and mobile homes. These uses account for over half of the total wool fiberglass production.[4] The decrease in the number of new houses constructed every year from 1979 to 1981 has resulted in a decreased demand for wool fiberglass insulation.[9,10] The number of new housing units built in 1982 is projected to be about 1.2 million, half that of the peak level of 2.4 million in 1972.[9,11] However, population growth in the prime age categories for household formation indicates a potential demand for new housing.[18] The home

TABLE 3-3. RANGE OF PROPERTIES OF WOOL FIBERGLASS INSULATION FOR VARIOUS USES[12-16]

Property	Range
Fiber diameter	0.001-0.016 mm (0.00004-0.0006 in.)
Density of end product	0.0048-0.13 g/cm^3 (0.3-8.0 lb/ft^3)
Maximum temperature limit[a]	96°-454°C (205°-850°F)

[a] Maximum surface temperature in contact with insulation under most favorable conditions. There is no low temperature limitation on fiberglass products.

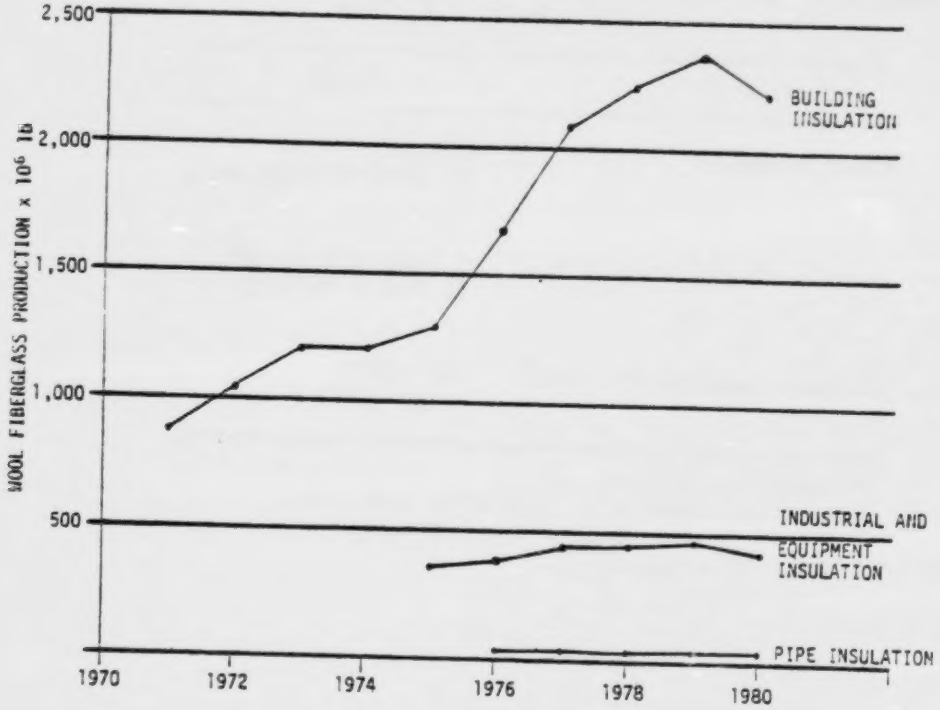


Figure 3-1. Growth in the wool fiberglass industry 1971-1980.[5,6,8,17]

building outlook for the next 5 years is dependent on what changes occur in the inflation rate, long-term interest rates, and general economic growth.

Residential retrofitting, primarily in response to high energy costs, has become a significant source of demand for wool fiberglass insulation.[19] One estimate concludes that as of 1980 there were at least 20 million units likely to add insulation and that demand would level off in 1983.[20]

The mobile home sector has been a growing market for insulation.[21] Although mobile home shipments have decreased since the peak levels of 1972 and 1973, the mobile home percentage of the total housing market has been increasing since 1979 due to the decrease in traditional housing starts.[22] With increased economic growth, greater access to mortgage financing, and an easing of restrictive zoning laws, mobile home shipments may increase during the next 5 years at an average annual rate of 5 to 10 percent.[22,23]

For the nonresidential building wall insulation market, wool fiberglass insulation competes with such products as urethane, styrene, and calcium silicate.[24] Roughly one-fifth of the total wool fiberglass insulation production is used in nonresidential buildings as roof, wall, and ventilation duct insulation. Total nonresidential insulation demand began to decrease in 1979.[25] Over the long term, office building and other private nonresidential construction is expected to increase substantially.[26]

Shipments of nonbuilding wool fiberglass insulation were steady from 1976 to 1980 and accounted for roughly 20 percent of the total wool fiberglass insulation production in those years.[5,6,17] Wool fiberglass meets approximately 50 percent of the appliance insulation market demand and about 43 percent of the pipe insulation market.[25]

Because building insulation is the main product of the wool fiberglass insulation industry, demand will increase when the construction industry, and particularly the housing industry, recovers from its current slump. The wool fiberglass insulation industry will be hesitant to undertake significant capacity expansion until demand strains current capacity.[3,27]

3.2 PROCESSES AND THEIR EMISSIONS

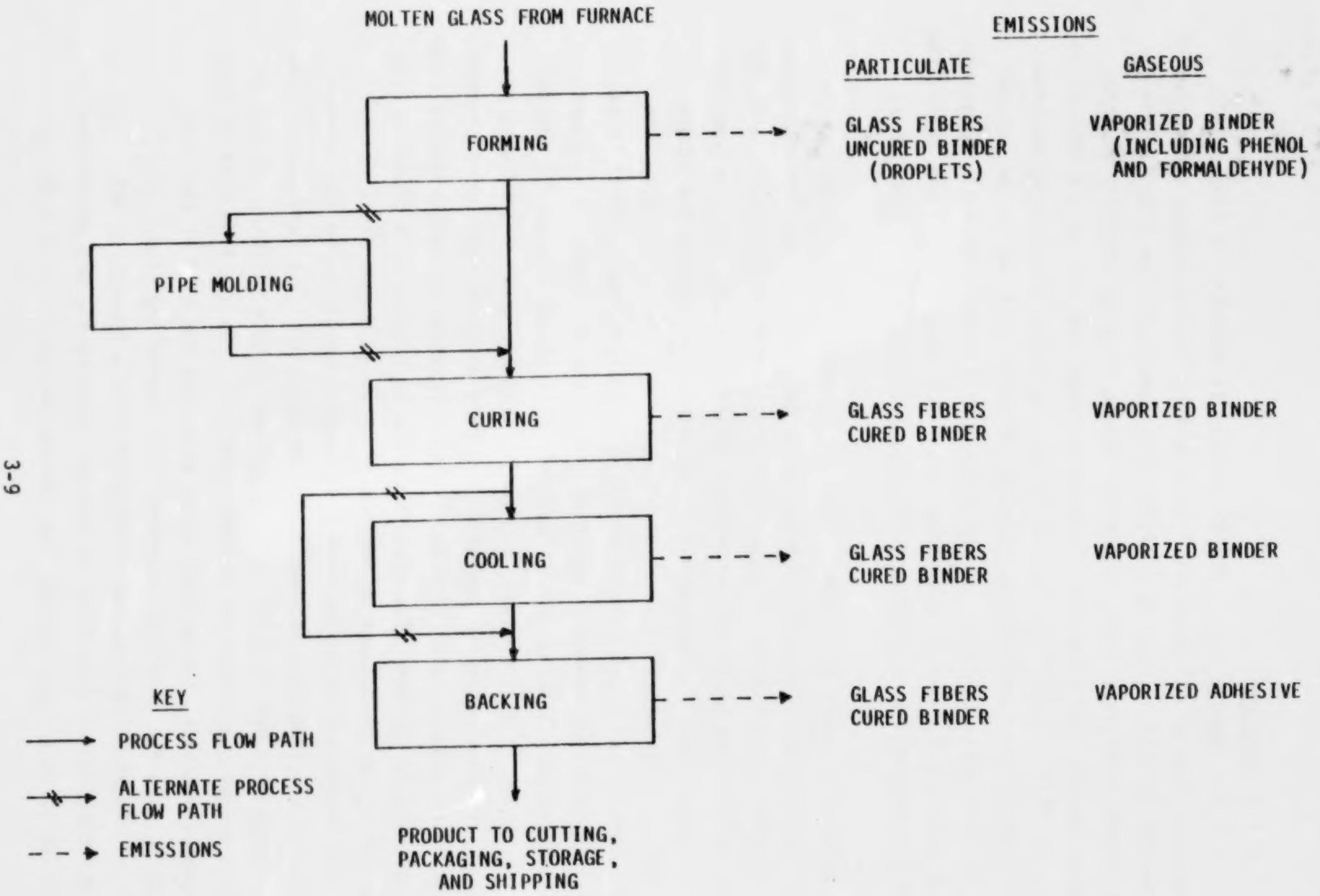
3.2.1 Process Description

3.2.1.1 General. A wool fiberglass production line consists of the following processes: (1) preparation of molten glass, (2) formation of fibers into a wool fiberglass mat, (3) curing the binder-coated fiberglass mat, (4) cooling the mat, and (5) backing, cutting, and packaging (Figure 3-2). The mat is formed on a conveyor, which then continues through the subsequent steps. Forming, curing, and cooling are the processes considered in this document. These three processes typically require about 60 meters (m) (200 feet [ft]) of the production conveyor. Fiberglass plants typically contain various sizes and types of production lines.

Two methods of forming fibers are used by the industry. In the RS process, centrifugal force causes molten glass to flow through small holes in the wall of a rapidly rotating cylinder. In the FA process, molten glass flows by gravity from a furnace to form threads that are then attenuated (stretched to the point of breaking) with air and/or flame.

After the fibers are formed, they are sprayed with a binder and collected as a mat on a moving conveyor. The conveyor carries the newly formed mat through an oven for curing of the thermosetting resin and then through a cooling section. (Some products do not require curing and/or cooling.) The cooled mat remains on the conveyor for trimming of the uneven edges. A backing is then applied with an adhesive to form a vapor barrier. The type of backing used depends on the product. The mat is then cut into desired widths and lengths and packaged. The trimmed edge waste (≦8 percent of final product), along with fibrous dust that develops during the cutting and packaging operations, is collected by a cyclone and diverted to a hammer mill to be chopped into a blowing wool product (loose insulation) or is recycled to the forming section and used as an admix.[28-32]

The air flow rates for wool fiberglass production lines vary with company practice, product, and line size. For RS lines, the greatest variation in air flow rates is from company to company. Typically, more process air is used to manufacture light density products than is used to manufacture heavy density products.[33] In response to the historical increase in energy costs, newer lines typically use less process air than older lines.[33]


MOLTEN GLASS FROM FURNACE
FORMING
PIPE MOLDING
CURING
COOLING
BACKING
PRODUCT TO CUTTING, PACKAGING, STORAGE, AND SHIPPING
EMISSIONS
PARTICULATE
GASEOUS
GLASS FIBERS
UNCURED BINDER
(DROPLETS)
VAPORIZED BINDER
(INCLUDING PHENOL AND FORMALDEHYDE)
GLASS FIBERS
CURED BINDER
VAPORIZED BINDER
GLASS FIBERS
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VAPORIZED BINDER
GLASS FIBERS
CURED BINDER
VAPORIZED ADHESIVE
KEY
PROCESS FLOW PATH
ALTERNATE PROCESS FLOW PATH
EMISSIONS

Figure 3-2. Wool fiberglass manufacturing process diagram.

3.2.1.2 Forming

3.2.1.2.1 Rotary spin. The RS process is depicted in Figure 3-3. A regulated flow of molten glass from a melting furnace enters the center of a rotating spinner. There is a linear arrangement of from 2 to 12 spinners on a single fiberglass line. The total amount of glass entering all the spinners on one line (glass pull rate) can range from 0.9 to 5.4 Mg/h (1 to 6 tons/h).[34-37] Centrifugal action forces the molten glass onto the inner wall of the spinner and through hundreds of small orifices in the spinner wall to form glass threads. As the threads of molten glass exit the spinner, a high velocity air jet or a mixture of air and natural gas flame forces the threads downward. This process attenuates the threads to produce glass fibers.

After the fibers are formed, they are sprayed with the binder. The binder spray ring is usually attached to an open cylinder or "bucket" below each spinner (Figure 3-3). A water overspray sometimes precedes the binder sprays to cool the glass and minimize volatilization and early polymerization of the binder.[38] The purpose of the binder is to hold the fibers together and its composition varies with product type. Typically, the binder consists of a solution of phenol-formaldehyde resin, water, urea, lignin, silane, and ammonia. Coloring agents may be added. Most companies purchase the phenol-formaldehyde resin at 50 to 55 percent solids concentration, store it at the plant, and mix it with the other ingredients as needed. The resin dilution operation can be a batch or continuous process. In the batch process, the resin is diluted with water in vented mixing tanks and then stored for use. The continuous mixing process is a closed system where the binder is diluted automatically on an as-needed basis.

The fiberglass is pulled onto a conveyor directly below the spinners by suction air from fans located under the conveyor. The forming air flow rates range from 566 to 5,660 cubic meters per minute (m^3/min) (20,000 to 200,000 actual cubic feet per minute [acfm]).[39] The air flow rate depends on company practice, the product being made, and the size of the line. Typically, the air flow rate increases with increasing line size.

The fibers collect on the conveyor to form a fiberglass mat. Each spinner contributes spun glass to the mat, causing the mat to increase in thickness as it travels through the forming section (Figure 3-3). The

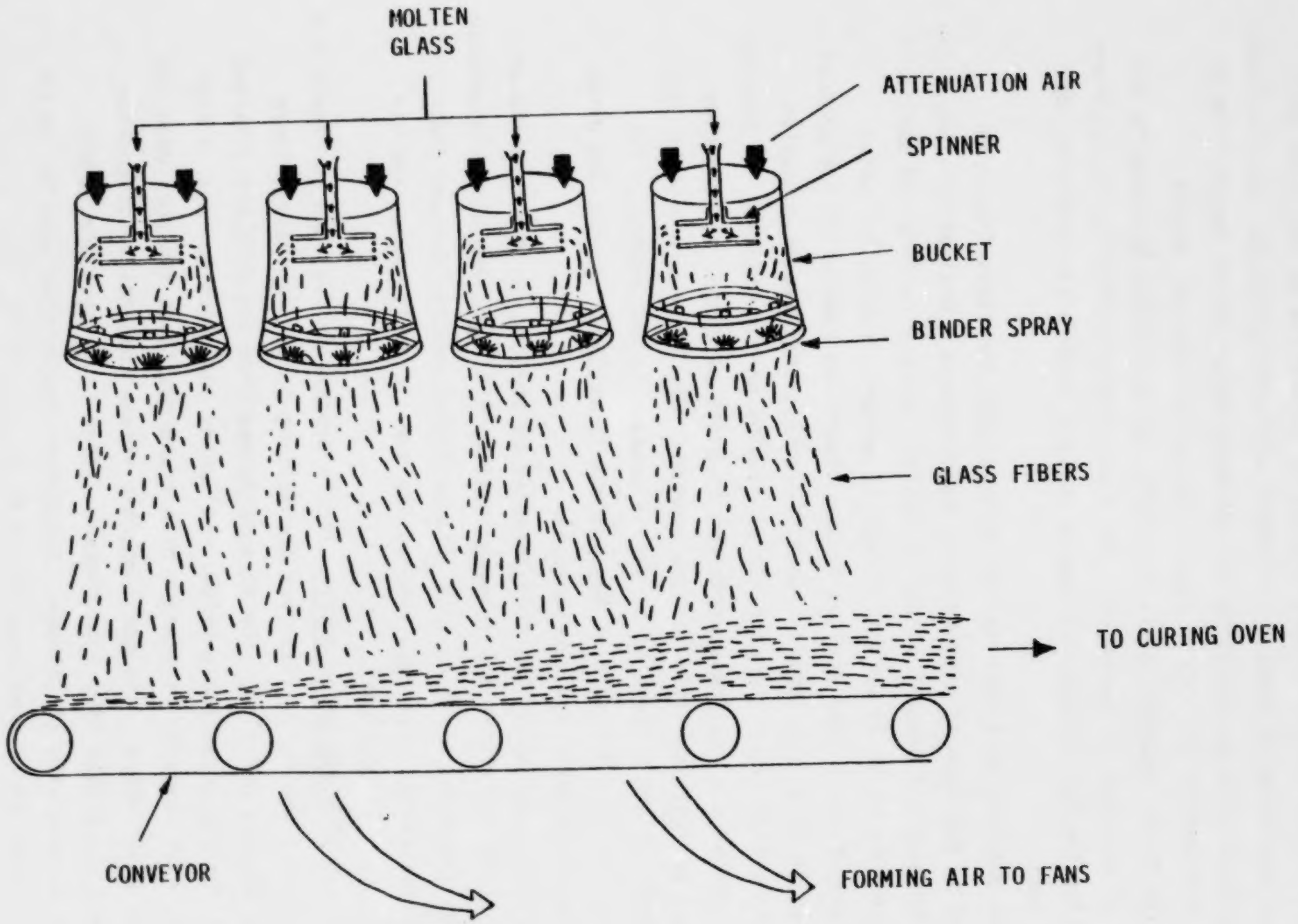
MOLTEN
GLASS
ATTENUATION AIR
SPINNER
BUCKET
BINDER SPRAY
GLASS FIBERS
TO CURING OVEN
CONVEYOR
FORMING AIR TO FANS

Figure 3-3. Rotary spin process.

thickness of the uncured fiberglass mat is controlled by the glass pull rate and the conveyor speed. To produce different products, mat thickness is usually altered by adjusting the conveyor speed, which ranges from 23 to 116 centimeters per second (cm/s) (45 to 228 feet per minute [ft/min]).[40-43] However, glass pull rate can be altered by changing the number of spinners in operation. The final product thickness is achieved by passing the mat between adjustable rollers immediately preceding the curing oven.

The quantity of binder solids sprayed onto the glass fibers is governed by the type of product being manufactured. Residential insulation is approximately 4 percent binder by weight, whereas roofing and appliance insulation are up to 25 percent binder by weight. Typically, about 70 percent of the binder applied to the fiberglass remains on the product (referred to as binder application efficiency); the rest is exhausted with the forming or curing oven air or remains on the conveyor.[44] Quality control checks are routinely performed by plant personnel to determine the "loss on ignition" (LOI) of the product. The LOI check ensures that the correct weight percent of binder is present in the product. To determine the LOI, a sample of the product is weighed, ignited and dried to remove the binder, and reweighed.[45]

A process variation has been patented by one company and consists of recirculating air within the forming section.[46,47] Recirculation reportedly decreases the total air flow rate into pollution control devices and, thus, decreases the size requirements for the air ducts, fans, and air pollution control equipment.

3.2.1.2.2 Flame attenuation. The FA process is depicted in Figure 3-4. Molten glass flows by gravity from the melting pots. Typically, there are 6 to 28 pots per line. The strands formed from the pots are directed by pinch rollers immediately below. Following the pinch rollers, a high velocity, high temperature mixture of air and gas flame impinges upon the fibers at a 90° angle. The gas flame/air stream combination attenuates the fibers and breaks them into pieces. After the fibers are formed, they are sprayed with the binder. The binder composition used in the FA process is similar to that used in the RS process.[48-51]

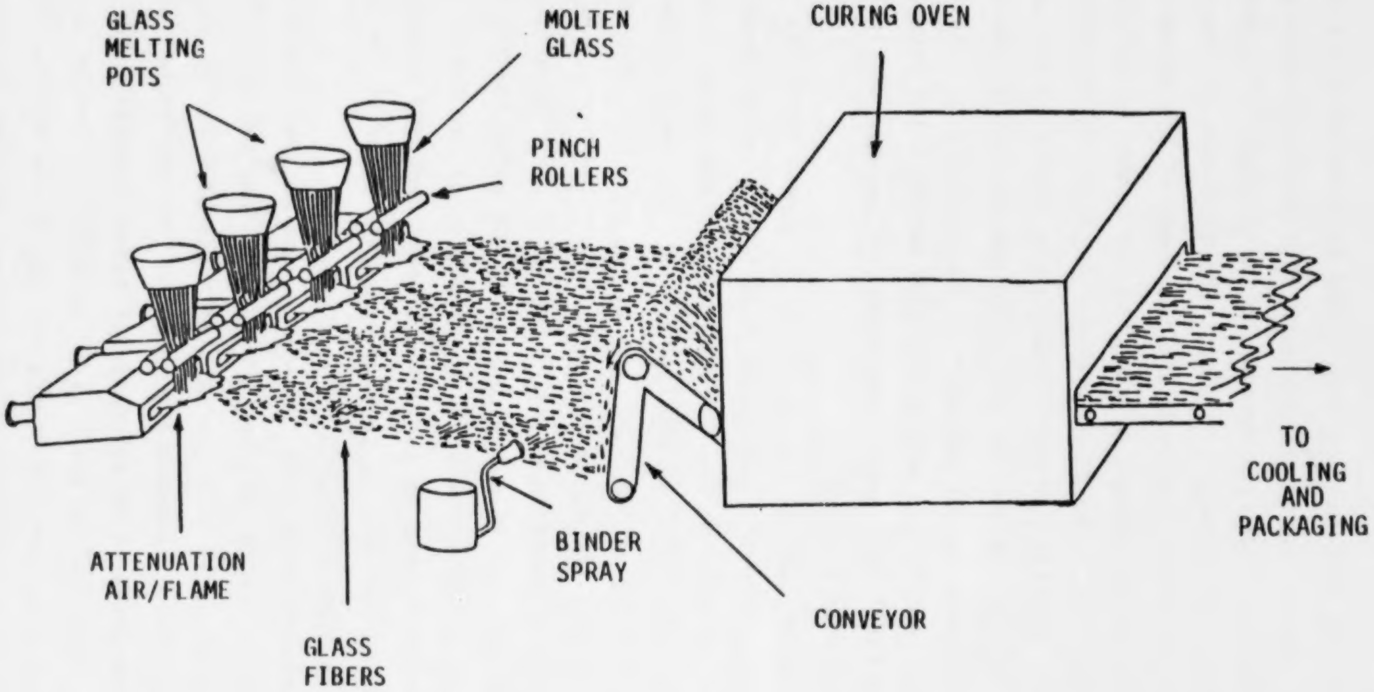
GLASS MELTING POTS
MOLTEN GLASS
CURING OVEN
PINCH ROLLERS
TO COOLING AND PACKAGING
ATTENUATION AIR/FLAME
BINDER SPRAY
CONVEYOR
GLASS FIBERS

Figure 3-4. Flame attenuation process.

Air, at a flow rate ranging from 2,830 to 5,094 m^3/min (100,000 to 180,000 acfm), forces the fibers downward onto the continuously moving conveyor.[39] The air flow rate depends on the product being made, the size of the line, and company practice. The thickness of the collected mat depends on the glass pull rate and the speed of the conveyor. The glass pull rate can be changed by changing the number of melting pots in operation on the line. The final product thickness is achieved by passing the mat between adjustable rollers immediately preceding the curing oven.

3.2.1.3 Curing. After the mat is formed (by either the RS or FA process), it proceeds on the conveyor to the curing oven (see Figure 3-5). Rollers located immediately before the oven compress the fiberglass mat to the desired final thickness. The clearance between the rollers can be adjusted for different products.

The curing oven drives off the moisture remaining on the fibers and sets the binder. An oven usually has from four to seven zones. The temperature of the oven varies for each product and ranges from approximately 175° to 315°C (350° to 600°F).[42,52-54] The temperature within each zone may also be varied depending on the product. Fans are used to draw hot air through the mat within each zone. The hot air may be recycled within each zone to conserve energy. The total air flow exiting the oven ranges from 85 to 1,415 m^3/min (3,000 to 50,000 acfm) for the RS process and from 283 to 708 m^3/min (10,000 to 25,000 acfm) for the FA process.[39] The air flow rate depends on the product being made and company practice. Residence time in the oven is controlled by the speed of the conveyor and varies with the type of product being produced.

In the production of pipe insulation, the uncured fiberglass mat is cut to a specific length, wrapped around a cylindrical mold called a mandrel, and then cured in either a pipe press or a curing oven. In the pipe press operation, mandrels are inserted into perforated casings within the pipe press in an automated or manual process. Air at temperatures ranging from 135° to 425°C (275° to 800°F) is forced through the casing in a pulse to cure the fiberglass mat on the mandrel.[54,55] Alternatively, in a continuous curing process for pipe insulation, the fiberglass-wrapped mandrels are transported by a conveyor through a typical curing oven.

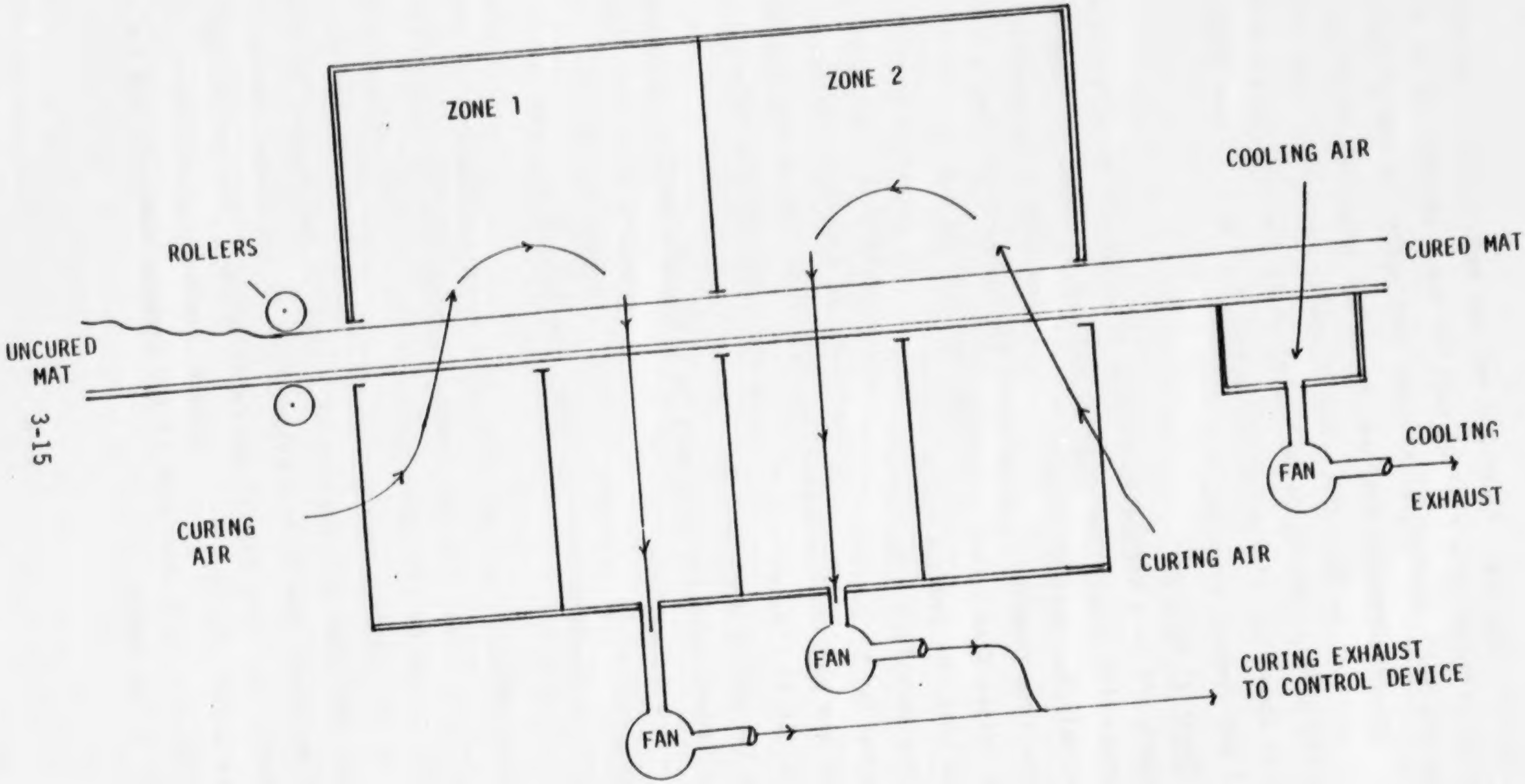
ZONE 1
ZONE 2
COOLING AIR
ROLLERS
CURED MAT
UNCURED MAT
COOLING
FAN
EXHAUST
CURING AIR
CURING AIR
FAN
FAN
CURING EXHAUST TO CONTROL DEVICE

Figure 3-5. Cut-away side view of curing oven and cooling section.

3.2.1.4 Cooling. After the mat has been cured in the curing oven, it may be conveyed to a cooling section where ambient air is drawn down through the mat. Cooling eliminates "hot spots" in the product that can cause fires and prevents overheating of the adhesive, which can cause the backing material to peel off. The RS cooling air flow rates range from 8.5 to 679 m^3/min (300 to 24,000 acfm) while the cooling air flow rate for FA is about 283 m^3/min (10,000 acfm).[39] The air flows depend on the product and company practice.

3.2.2 Material Balance

Figure 3-6 is a schematic diagram of a typical material balance for an RS production line. The material balance is based on industry data and measured emission data.[56] Industry data show that a representative material input rate into forming is three times the production rate, χ. It follows that the losses from forming, curing, and cooling are 2χ. Emission test data show that the average ratio of particulate emissions from forming to particulate emissions from curing is approximately 12:1 and that losses from cooling may be neglected without loss of accuracy. Assuming that both water and particulate matter are lost from forming and curing in the same ratio (12:1), losses from forming are 1.8χ, and the material input rate into the curing oven is 1.2χ.

Insufficient data are available to estimate a material balance for FA lines to the extent shown for RS lines. Industry data show, however, that the material input rate into forming is higher for FA lines than for RS lines and is approximately four times the production rate, χ.

3.2.3 Process Emissions

The three emission sources considered in this document, for both RS and FA production lines, are the forming, curing, and cooling sections. Emissions are caused by (1) vaporization of the volatile compounds from the binder in the forming, curing, and cooling sections and (2) entrainment of fiberglass particles and droplets of binder in the process air stream. The gaseous emissions result from evaporation of the binder and consist of hydrocarbons, including phenol and formaldehyde. The particulate emissions are sticky and consist of binder droplets, glass fibers, and liquid droplets that form when some of the gaseous compounds are cooled and condensed in the ducts.

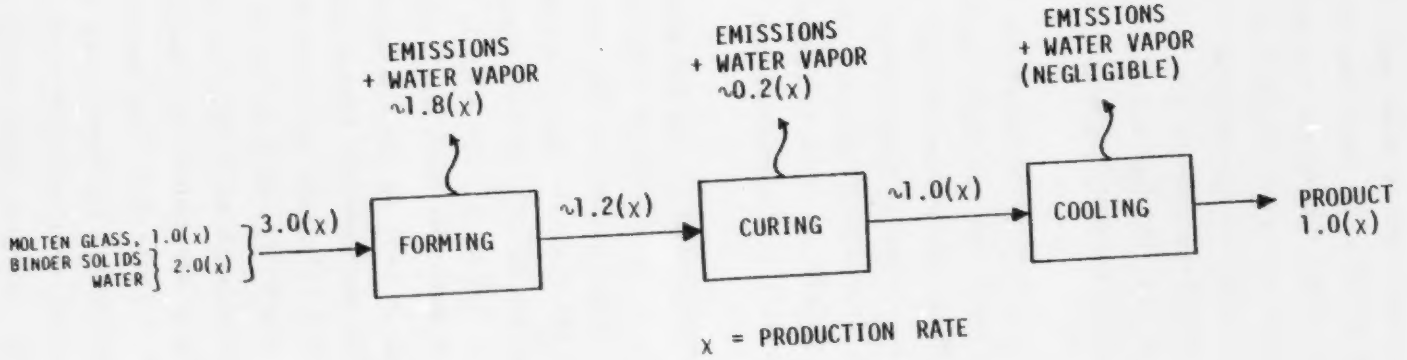
EMISSIONS
+ WATER VAPOR
∿1.8(x)
EMISSIONS
+ WATER VAPOR
∿0.2(x)
EMISSIONS
+ WATER VAPOR
(NEGLIGIBLE)
MOLTEN GLASS, 1.0(x)
BINDER SOLIDS
WATER
2.0(x)
3.0(x)
FORMING
∿1.2(x)
CURING
∿1.0(x)
COOLING
PRODUCT
1.0(x)
x = PRODUCTION RATE

Figure 3-6. Typical material balance for rotary spin production line.

For a given wool fiberglass line, emission rates may be different for different products. Four product groups have been identified that are representative of the range of emission rates and emission controllability expected to occur in the wool fiberglass industry.[57] These four product groups are building insulation, pipe insulation, ductboard, and heavy density insulation. The manufacturing processes for these product groups involve differences in parameters such as the solids content of the binder, the binder content of the finished mat (LOI), and the thickness and density of the mat, all of which cause differences in emission rates.[44,58,59]

It should be noted that most uncontrolled emissions reported in this document were measured after the emissions had been reduced by process modifications or after the gas stream had passed through low pressure drop scrubbers, cyclones, or water sprays in the ductwork. Measurement of totally uncontrolled emissions from wool fiberglass insulation manufacturing lines is generally not possible. This is because process modifications and prohibitive ductwork configurations are used widely in this industry.

Nine RS and three FA lines were tested during the production of six different products. The six products were: (1) R-11 building insulation, (2) R-19 building insulation, (3) pipe insulation, (4) air ductboard, (5) heavy density insulation, and (6) flexible duct. A summary of uncontrolled emissions for particulate matter, phenol, phenolic compounds, and formaldehyde is shown in Tables 3-4 to 3-7 for both RS and FA production lines. The emissions are given for both the individual sections of the line (forming, curing, and cooling) as well as for the total line.

The product density and LOI for each product tested are presented in Table 3-8 and range from 8.2 to 118.5 kilograms per cubic meter (kg/m^3) (0.5 to 7.4 pounds per cubic foot [lb/ft^3]) and from 3.9 to 18 percent, respectively. The process conditions (such as production rate, temperature, and air flow rates) during these tests are deemed confidential by the manufacturers and are not reported in Table 3-8. The operating conditions encountered during the tests are considered representative of normal operation for the production lines that were tested.[60-64]

3.2.3.1 Emissions From Forming. Average uncontrolled particulate emissions from the forming section on eight RS and three FA lines ranged

TABLE 3-4. SUMMARY OF UNCONTROLLED PARTICULATE EMISSION DATA[a] 65-70

Line	Product[b]	Line type[c]	Forming		Curing		Curing and cooling		Cooling		Backing		Total emissions	
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
A1	R-11	RS	$55.6^{d,e}$	111.2	$2.2^{d,e}$	4.4	--	--	--	--	--	--	} 57.8	115.6
A1	R-11	RS	--	--	--	--	--	--	0.1	0.2	--	--		
A2	R-19	RS	$20.4^{d,e}$	40.8	$1.9^{d,e}$	3.8	--	--	--	--	--	--	} 22.4	44.8
A2	R-19	RS	--	--	--	--	--	--	0.1	0.2	--	--		
A3	DB	RS	$34.2^{d,e}$	68.4	$2.0^{d,e}$	4.1	--	--	--	--	--	--	} 36.3	72.6
A3	DB	RS	--	--	--	--	--	--	0.1	0.2	--	--		
B	HDI	RS	$6.1^{d,e,f}$	12.1	--	--	--	--	--	--	--	--	--	--
C	R-11	RS	87.0^{f}	174.0	--	--	--	--	0.1	0.1	0^{g}	0.1	--	--
D	R-11	RS	$4.8^{d,f,h}$	9.7	0.7^{d}	1.4	1.0	2.0	0.3^{d}	0.6	$0^{d,g}$	0	5.7	11.7
E	DB	RS	12.2^{f}	24.4	--	--	--	--	--	--	0^{g}	0	--	--
F	R-11	RS	5.0	10.0	--	--	2.3	4.6	--	--	--	--	7.3	14.6
G	PI	RS	7.1	14.2	--	--	--	--	--	--	--	--	7.1	14.2
H	PI	RS	--	--	5.7	11.3	--	--	--	--	--	--	5.7	11.3
I	DB	FA	44.4	88.7	--	--	3.0	5.9	0.3	0.6	--	--	47.3	94.6
J	R-11	FA	24.4	48.8	2.3	4.6	--	--	--	--	--	--	26.7	53.4
K	PI	FA	32.9	65.8	--	--	--	--	--	--	--	--	32.9	65.8
K	FD	FA	37.0	74.0	5.3	10.6	--	--	--	--	--	--	42.3	84.6
L	R-19	RS	$3.5^{f,h}$	7.0	--	--	0.9^{d}	1.8	--	--	--	--	4.3	8.6

[a] Average of test runs; total catch analysis; total organic carbon analysis of back half. Sum of forming plus curing plus cooling may not equal total emissions due to rounding error.

[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. PI = pipe insulation. FD = flexible duct. HDI = heavy density insulation.

[c] RS = rotary spin. FA = flame attenuation.

[d] Water sprays in duct prior to sampling point.

[e] Low pressure drop scrubber(s) in duct prior to sampling point.

[f] Process modifications used.

[g] Values are <0.025 kg/Mg (<0.05 lb/ton), but due to rounding to one decimal place are recorded here as 0.

[h] Cyclone separator(s) in duct prior to sampling point.

TABLE 3-5. SUMMARY OF UNCONTROLLED PHENOL EMISSION DATA[a] 65-70

Line	Product[b]	Line type[c]	Forming		Curing		Curing and cooling		Cooling		Backing		Total emissions	
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
A1	R-11	RS	1.5[d,e]	3.0	0.1[d,e]	0.2	--	--	--	--	--	--	1.6	3.2
A1	R-11	RS	--	--	--	--	--	--	0	0	--	--		
A2	R-19	RS	0.9[d,e]	1.8	0.1[d,e]	0.2	--	--	--	--	--	--	1.0	2.0
A2	R-19	RS	--	--	--	--	--	--	0	0	--	--		
A3	DB	RS	3.6[d,e]	7.2	0.2[d,e]	0.5	--	--	--	--	--	--	3.8	7.7
A3	DB	RS	--	--	--	--	--	--	0	0	--	--		
B	HDI	RS	0.5[d,e,f]	1.0	--	--	--	--	--	--	--	--	--	--
C	R-11	RS	1.7[f]	3.4	--	--	--	--	0	0	0[g]	0	--	--
D	R-11	RS	0.5[d,f,h]	1.0	0[d,g]	0.1	--	--	0[d,g]	0.1	0[d]	0	0.5	1.1
E	DB	RS	2.4[f]	4.9	--	--	--	--	--	--	0[g]	0	--	--
F	R-11	RS	0.8	1.6	--	--	0.1	0.1	--	--	--	--	0.9	1.7
G	PI	RS	1.9	3.9	--	--	--	--	--	--	--	--	1.9	3.9
H	PI	RS	--	--	0.2	0.4	--	--	--	--	--	--	0.2	0.4
I	DB	FA	4.7	9.5	--	--	0[g]	0.1	0[g]	0	--	--	4.7	9.6
J	R-11	FA	1.2	2.5	0[g]	0.1	--	--	--	--	--	--	1.2	2.5
K	PI	FA	1.4	2.8	--	--	--	--	--	--	--	--	1.4	2.8
K	FD	FA	5.1	10.2	0.2	0.4	--	--	--	--	--	--	5.3	10.6
L	R-19	RS	0.5[f,h]	1.1	--	--	0.1[d]	0.2	--	--	--	--	0.6	1.3

[a] Average of test runs; total catch analysis; gas chromatographic analysis.
[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. PI = pipe insulation. FD = flexible duct.
HDI = heavy density insulation.
[c] RS = rotary spin. FA = flame attenuation.
[d] Water sprays in duct prior to sampling point.
[e] Low pressure drop scrubber(s) in duct prior to sampling point.
[f] Process modifications used.
[g] Values are <0.025 kg/Mg (<0.05 lb/ton), but due to rounding to one decimal place are recorded here as 0. A value of zero without this footnote means no compound was detected.
[h] Cyclone separator(s) in duct prior to sampling point.

TABLE 3-6. SUMMARY OF UNCONTROLLED PHENOLIC COMPOUND EMISSION DATA[a] 65-70

Line	Product[b]	Line type[c]	Forming		Curing		Curing and cooling		Cooling		Backing		Total emissions	
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
A1	R-11	RS	15.0[d,e]	30.1	0.5[d,e]	1.1	--	--	--	--	--	--	15.5	31.2
A1	R-11	RS	--	--	--	--	--	--	0	0	--	--		
A2	R-19	RS	2.9[d,e]	5.7	0.4[d,e]	0.8	--	--	--	--	--	--	3.3	6.6
A2	R-19	RS	--	--	--	--	--	--	0[f]	0.1	--	--		
A3	DB	RS	9.8[d,e]	19.5	0.9[d,e]	1.8	--	--	--	--	--	--	10.7	21.3
A3	DB	RS	--	--	--	--	--	--	0	0	--	--		
B	HDI	RS	0.9[d,e,g]	1.7	--	--	--	--	--	--	--	--	--	--
C	R-11	RS	15.1[g]	30.3	--	--	--	--	0[f]	0	0[f]	0	--	--
D	R-11	RS	1.5[d,g,h]	3.0	0.2[d]	0.3	--	--	0.1[d]	0.1	0[d]	0	1.7	3.5
E	DB	RS	5.2[g]	10.4	--	--	--	--	--	--	0	0	--	--
F	R-11	RS	1.4	2.9	--	--	0.5	1.0	--	--	--	--	1.9	3.8
G	PI	RS	3.0	6.1	--	--	--	--	--	--	--	--	3.0	6.1
H	PI	RS	--	--	2.5	5.0	--	--	--	--	--	--	2.5	5.0
I	DB	FA	12.0	24.1	--	--	0.4	0.8	0	0	--	--	12.4	24.9
J	R-11	FA	3.3	6.6	0.2	0.4	--	--	--	--	--	--	3.5	7.0
K	PI	FA	16.4	32.8	--	--	--	--	--	--	--	--	16.4	32.8
K	FD	FA	16.4	32.8	1.5	3.1	--	--	--	--	--	--	17.9	35.9
L	R-19	RS	1.3[g,h]	2.6	--	--	0.2[d]	0.4	--	--	--	--	1.5	3.0

[a] Average of test runs; total catch analysis; wet chemical analysis.

[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. PI = pipe insulation. FD = flexible duct. HDI = heavy density insulation.

[c] RS = rotary spin. FA = flame attenuation.

[d] Water sprays in duct prior to sampling point.

[e] Low pressure drop scrubber(s) in duct prior to sampling point.

[f] Values are <0.025 kg/Mg (<0.05 lb/ton), but due to rounding to one decimal place are recorded here as 0. A value of zero without this footnote means no compound was detected.

[g] Process modifications used.

[h] Cyclone separator(s) in duct prior to sampling point.

TABLE 3-7. SUMMARY OF UNCONTROLLED FORMALDEHYDE EMISSION DATA[a] 65-70

Line	Product[b]	Line type[c]	Forming kg/Mg	Forming lb/ton	Curing kg/Mg	Curing lb/ton	Curing and cooling kg/Mg	Curing and cooling lb/ton	Cooling kg/Mg	Cooling lb/ton	Backing kg/Mg	Backing lb/ton	Total emissions kg/Mg	Total emissions lb/ton
A1	R-11	RS	1.7[d,e]	3.5	0.2[d,e]	0.4	--	--	--	--	--	--	1.9	3.9
A1	R-11	RS	--	--	--	--	--	--	0	0	--	--		
A2	R-19	RS	0.6[d,e]	1.2	0.2[d,e]	0.3	--	--	--	--	--	--	0.8	1.5
A2	R-19	RS	--	--	--	--	--	--	0	0	--	--		
A3	DB	RS	2.3[d,e]	4.5	0.1[d,e]	0.2	--	--	--	--	--	--	2.4	4.7
A3	DB	RS	--	--	--	--	--	--	0	0	--	--		
B	HDI	RS	0.4[d,e,f]	0.9	--	--	--	--	--	--	--	--	--	--
C	R-11	RS	5.4[f]	10.9	--	--	--	--	0[g]	0	0	0	--	--
D	R-11	RS	0.8[d,f,h]	1.6	0.1[d]	0.2	--	--	0[d,g]	0.1	0[d]	0	1.0	1.9
E	DB	RS	1.4[f]	2.8	--	--	--	--	--	--	0	0	--	--
F	R-11	RS	0.6	1.1	--	--	0.7	1.4	--	--	--	--	1.3	2.6
G	PI	RS	0.3	0.7	--	--	--	--	--	--	--	--	0.3	0.7
H	PI	RS	--	--	0.3	0.7	--	--	--	--	--	--	0.3	0.7
I	DB	FA	9.4	18.7	--	--	0.2	0.4	0	0	--	--	9.5	19.1
J	R-11	FA	4.4	8.7	0.5	0.9	--	--	--	--	--	--	4.8	9.6
K	PI	FA	1.8	3.5	--	--	--	--	--	--	--	--	1.8	3.5
K	FD	FA	3.0	6.0	0.6	1.1	--	--	--	--	--	--	3.5	7.0
L	R-19	RS	0.7[f,h]	1.4	--	--	0.1[d]	0.2	--	--	--	--	0.8	1.6

[a] Average of test runs; total catch analysis.

[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. PI = pipe insulation. FD = flexible duct. HDI = heavy density insulation.

[c] RS = rotary spin. FA = flame attenuation.

[d] Water sprays in duct prior to sampling point.

[e] Low pressure drop scrubber(s) in duct prior to sampling point.

[f] Process modifications used.

[g] Values are <0.025 kg/Mg (<0.05 lbton), but due to rounding to one decimal place are recorded here as 0. A value of zero without this footnote means no compound was detected.

[h] Cyclone separator(s) in duct prior to sampling point.

TABLE 3-8. SUMMARY OF PRODUCTION PARAMETERS FOR UNCONTROLLED EMISSION DATA[71-75]

Line	Product[a]	Line type[b]	Average product density kg/m³	Average product density lb/ft³	Average product LOI, %
A	DB	RS	65.7	4.1	15
A	R-19	RS	9.3	0.58	4.5
A	R-11	RS	9.8	0.61	4.5
B	HDI	RS	118.5	7.4	10.6
C	R-11	RS	10.4	0.65	4.3
D	R-11	RS	9.1	0.57	3.9
E	DB	RS	65.7	4.1	14.7
F	R-11	RS	10.6	0.66	6.0
G	PI	RS	13.6	0.85	9.0
H	PI	RS	76.1	4.75	--
I	DB	FA	54.5	3.4	17.3
J	R-11	FA	12.3	0.77	6.5
K	PI	FA	12.5	0.78	18
K	FD	FA	21.5	1.34	15
L	R-19	RS	8.2	0.5	4.6

[a] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. PI = pipe insulation. FD = flexible duct. HDI = heavy density insulation.

[b] RS = rotary spin. FA = flame attenuation.

from 3.5 to 87.0 kg/Mg (7.0 to 174.0 lb/ton) for RS and from 24.4 to 44.4 kg/Mg (48.8 to 88.7 lb/ton) for FA. The average of the phenolic compound emissions ranged from 0.9 to 15.1 kg/Mg (1.7 to 30.3 lb/ton) for RS and from 3.3 to 16.4 kg/Mg (6.6 to 32.8 lb/ton) for FA. Average formaldehyde emissions ranged from 0.3 to 5.4 kg/Mg (0.7 to 10.9 lb/ton) for RS and from 1.8 to 9.4 kg/Mg (3.5 to 18.7 lb/ton) for FA. Average phenol emissions ranged from 0.5 to 3.6 kg/Mg (1.0 to 7.2 lb/ton) for RS and from 1.2 to 5.1 kg/Mg (2.5 to 10.2 lb/ton) for FA.

3.2.3.2 Emissions From Curing. The range of average uncontrolled curing process emissions for three RS lines was 0.7 to 5.7 kg/Mg (1.4 to 11.3 lb/ton) for particulate matter, 0.2 to 2.5 kg/Mg (0.3 to 5.0 lb/ton) for phenolic compounds, 0.1 to 0.3 kg/Mg (0.2 to 0.7 lb/ton) for formaldehyde, and trace to 0.2 kg/Mg (0.1 to 0.5 lb/ton) for phenol. The range of emissions for two FA lines was 2.3 to 5.7 kg/Mg (4.6 to 11.3 lb/ton) for particulate matter, 0.2 to 2.5 kg/Mg (0.4 to 5.0 lb/ton) for phenolic compounds, 0.3 to 0.6 kg/Mg (0.7 to 1.1 lb/ton) for formaldehyde, and trace to 0.2 kg/Mg (0.1 to 0.4 lb/ton) for phenol.

3.2.3.3 Emissions From Cooling Operations. For the RS cooling process, the ranges of average uncontrolled emissions for three RS lines were 0.1 to 0.3 kg/Mg (0.2 to 0.6 lb/ton), 0 to 0.1 kg/Mg (0 to 0.1 lb/ton), 0 to a trace kg/Mg (0 to 0.1 lb/ton), and 0 to a trace kg/Mg (0 to 0.1 lb/ton) for particulate matter, phenolic compounds, formaldehyde, and phenol, respectively. Only one FA cooling process was sampled; no phenol, phenolic compounds, or formaldehyde was measured, and 0.3 kg/Mg (0.6 lb/ton) particulate matter was reported.

3.2.3.4 Emissions From Other Processes. Emissions were measured from the backing operations of three RS lines, where the paper or foil backing was applied to the fiberglass mat. Only trace particulate emissions (0 to 0.1 lb/ton) were recorded. No phenolic or formaldehyde compounds and only a trace of phenol were found. Emissions from the trimming, cutting, and packaging operations were not measured because fiberglass material from these operations is typically recycled to the forming section or reprocessed into blowing wool insulation.

3.2.3.5 Annual Emissions Estimates. Table 3-9 presents a summary of uncontrolled emission levels, in megagrams per year and tons per year, for particulate matter, phenol, phenolic compounds, and formaldehyde. These estimates are based on actual uncontrolled emission data applied to four typical RS line sizes.

3.3 BASELINE EMISSIONS

The baseline emission level is the level of control that would be achieved by the industry in the absence of a new source performance standard (NSPS). Typically, this level of control reflects the emission levels required under existing State Implementation Plans (SIP's) and local regulations. The baseline is used to evaluate the impacts of various regulatory alternatives.

Often the average value of allowable emissions under SIP's are used to represent baseline. However, for this study, the average values of the allowable emissions under various SIP's are difficult to use with any confidence to represent baseline for the following reasons. The test method developed by the EPA for this study is based on a total catch analysis (EPA Method 5 filter catch plus total organic carbon analysis of the impinger catch) whereas the test methods used by the States for measurement of particulate emissions typically specify only front-half (filter) catch. There are no States that utilize a test method identical to the one developed by the EPA. In addition, there is a wide variation in the level of control required by various States, as shown in Table 3-10. For example, allowable emissions for a typical RS fiberglass line producing 34,000 Mg (38,000 tons) of insulation per year can range from 9.5 to 51.2 kg/h (21 to 113 lb/h).

To establish a baseline, it was assumed that the most widely used control devices currently in use would be installed in the future to meet SIP's. To determine the most widely used control devices, a tabulation was made of the existing pollution control devices applied to RS lines. Of the 58 known RS lines in this industry, information on control device applications was available for 34 lines and is shown in Table 3-11. The most common device for control of forming emissions is a low pressure drop wet scrubber. The most common control device used on the curing exhaust gases is an incinerator. The majority of cooling processes are uncontrolled. Therefore, for baseline it is assumed that forming will be

TABLE 3-9. UNCONTROLLED EMISSION LEVELS FOR ROTARY SPIN LINES
Mg/yr (tons/yr)

Production, Mg/yr: (tons/yr):	4,500 (5,000)				18,000 (20,000)				34,000 (38,000)				50,000 (55,000)			
Pollutant	Fo[a]	Cu[b]	Co[c]	Total	Fo	Cu	Co	Total	Fo	Cu	Co	Total	Fo	Cu	Co	Total
Particulate matter[d]	119.3 (131.5)	11.3 (12.5)	0.7 (0.8)	131.3 (144.8)	477.2 (526.0)	45.4 (50.0)	2.7 (3.0)	525.3 (579.0)	906.6 (999.4)	86.2 (95.0)	9.2 (5.7)	998.0 (400.1)	1,312.2 (1,446.5)	124.7 (137.5)	7.5 (8.3)	1,444.4 (1,592.3)
Phenol	7.1 (7.8)	0.7 (0.8)	0.1 (0.1)	7.9 (8.7)	28.1 (31.0)	2.7 (3.0)	0.2 (0.2)	31.0 (34.2)	53.4 (58.9)	5.2 (5.7)	0.4 (0.4)	59.0 (65.0)	77.4 (85.3)	7.5 (8.3)	0.5 (0.6)	85.4 (94.2)
Phenolic compounds	27.7 (30.5)	4.1 (4.5)	0.1 (0.1)	31.9 (35.1)	110.7 (122.0)	16.3 (18.0)	0.4 (0.4)	127.4 (140.4)	210.3 (231.8)	31.0 (34.2)	0.7 (0.8)	242.0 (266.8)	304.4 (335.5)	44.9 (49.5)	1.0 (1.1)	350.3 (386.1)
Formaldehyde	6.8 (7.5)	0.7 (0.8)	0.1 (0.1)	7.6 (8.4)	27.2 (30.0)	2.7 (3.0)	0.5 (0.5)	30.4 (33.5)	51.7 (57.0)	5.2 (5.7)	0.9 (1.0)	57.8 (63.7)	74.8 (82.5)	7.5 (8.3)	1.3 (1.4)	83.6 (92.2)

[a] Forming.
[b] Curing.
[c] Cooling.
[d] Total catch (filter catch plus TOC analysis of impinger catch).

TABLE 3-10. SUMMARY OF STATE REGULATIONS FOR A TYPICAL ROTARY SPIN FIBERGLASS LINE

Production: 38,000 tons/yr
Total line air flow: 123,000 dscfm

State	Regulation	Equivalent line emission limits, lb/h[a]
California[b]		
Bay Area	$E = 4.1 \times P^{0.67}$[c]	49.1
SCAQMD[d]	Table 405(a)	30.4
Glenn Co.[d]	$E = 4.1 \times P^{0.67}$	49.1
Madera Co.	$E = 3.59 \times P^{0.62}$	38.6
Georgia	0.04 gr/dscf	42.2
Indiana	$E = 4.1 \times P^{0.67}$	49.1
Kansas	$E = 4.1 \times P^{0.67}$	49.1
Michigan	0.1 lb/1,000 lb gas (≡0.05 gr/dscf)	52.7
New Jersey	0.02 gr/dscf	21.1
New York	0.05 gr/dscf	52.7
Ohio[b]	$E = 4.1 \times P^{0.67}$	49.1
Pennsylvania[b]	0.02 to 0.04 gr/dscf (dependent on air flow)	42.2
Texas[b]	$E = 0.048\ q^{0.62}$ (q = acfm)	112.9
West Virginia	Table (Reg. 7, Sec. 2.01, Type a)	41.4

[a] kg/h = lb/h ÷ 2.205.
[b] Require best available control technology for new source.
[c] E = allowable emission rate in lb/h.
P = process weight rate in tons/h.
[d] Emission limits shown are based on total catch.

TABLE 3-11. EMISSION CONTROLS ON EXISTING ROTARY SPIN WOOL FIBERGLASS LINES[76]

Control device	No. of process sections Forming	 Curing	 Cooling
None (uncontrolled)	12	11	15
Low Δp wet scrubber (1.2 kPa/5-in. w.c.)	11	0	0
High Δp wet scrubber (8.7 kPa/35 in. w.c.)	1	1	1
Low temp. incinerator (316°C/600°F)	1	6	1
High temp. incinerator (704°C/1300°F)	0	6	0
HVAF[a]	0	4	6
Wet ESP[b]	9	4	2
Subtotal	34	32	25
Information not available	24	24	24
Total[c]	58	56	49

[a] HVAF = high velocity air filter.
[b] ESP = electrostatic precipitator.
[c] Some lines do not have curing and/or cooling sections.

controlled by a low pressure drop scrubber, curing will be controlled by an incinerator, and cooling will be uncontrolled.

To estimate the water and energy costs for the scrubber controlling forming emissions, a pressure drop of 1.2 kilopascals (kPa) (5 in. of water column [w.c.]) was selected because this is the most common pressure drop for the scrubbers identified in the survey. In addition, an efficiency of 50 percent was assumed. (The average nationwide efficiency for a low pressure drop scrubber controlling forming emissions cannot be precisely determined because there is not enough test data and because the particle size of fiberglass emissions cannot be measured.)

A low temperature incinerator was selected to represent average nationwide control of curing emissions under the SIP's. A control efficiency of zero percent was assumed for a baseline incinerator because low temperature incinerators are used only to meet opacity limits and are not used to reduce the mass of emissions.[77]

Based on the assumptions stated and using the average uncontrolled particulate emission data from the EPA test program, the following baseline emission levels are obtained for all RS line sizes: 13.15 kg/Mg (26.3 lb/ton) for forming, 2.5 kg/Mg (5.0 lb/ton) for curing, and 0.15 kg/Mg (0.3 lb/ton) for cooling. Therefore, the total line baseline emission limit is 15.8 kg/Mg (31.6 lb/ton). (Emission data from Line L were not used to compute the baseline emission limit because these data were not available when the baseline was developed.) Table 3-12 presents annual baseline emission levels for four different RS line sizes.

The determination of the baseline emission limit for FA production lines was based on EPA source test data for the FA line with the highest uncontrolled emissions. There is much less variation in typical FA line size, so only one baseline level is considered. The baseline emission levels for forming, curing, and cooling are 44.35 kg/Mg (88.7 lb/ton), 2.15 kg/Mg (5.3 lb/ton), and 0.3 kg/Mg (0.6 lb/ton), respectively. Thus, the total baseline emission limit for an FA line is 46.8 kg/Mg (94.6 lb/ton).

Nine of the eleven States listed in Table 3-10 regulate visible emissions from process exhaust stacks (forming, curing, and cooling) to a level of ≦20 percent opacity. The limit in two States is ≦40 percent. A

TABLE 3-12. BASELINE EMISSION LEVELS FOR ROTARY SPIN LINES
(English)

	Particulate emissions, tons/yr			
Line production, tons/yr	Forming	Curing	Cooling	Total
5,000	65.8	12.5	0.8	79.1
20,000	263.0	50.0	3.0	316.0
38,000	499.7	95.0	5.7	600.4
55,000	723.3	137.5	8.3	869.1

(Metric)

	Particulate emissions, Mg/yr			
Line production, Mg/yr	Forming	Curing	Cooling	Total
4,500	59.7	11.4	0.7	71.8
18,000	238.8	45.4	2.7	286.9
34,000	453.7	86.3	5.2	545.2
50,000	656.8	124.9	7.5	789.2

baseline control level of ≤20 percent opacity has been selected for visible emissions from process exhaust stacks (forming, curing, and cooling).

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4. EMISSION CONTROL TECHNIQUES

Emission control devices and techniques applicable to the forming, curing, and cooling operations in wool fiberglass manufacturing plants are described in this chapter. Emission data are presented and discussed for each control technique. Additional information on these emission tests is presented in Appendix C.

Table 4-1 presents the control techniques and common configurations used in the wool fiberglass industry to control individual sources or the combined emissions from two or more sources on wool fiberglass lines.

4.1 PROCESS MODIFICATIONS

Process modifications to the wool fiberglass manufacturing process, including forming air recirculation, special binder formulations, and water overspray rings, may affect emission levels. These process modifications may be used alone or with add-on control devices to reduce emissions. The modifications are integral parts of the production process, and specific details are considered to be confidential by each company.

4.1.1 Forming Air Recirculation

Forming air recirculation is a process modification in which a portion of the air exiting the forming chamber is recirculated to the forming section, and the remaining air is exhausted to a control device.[1,2] As discussed in Chapter 3, the use of forming air recirculation reduces the quantity of exhaust gas to be treated; therefore, the control device size can be reduced.

TABLE 4-1. EMISSION SOURCES AND CONTROL METHODS FOR WOOL FIBERGLASS INSULATION MANUFACTURING

Emission sources	Control technology
Forming	Wet electrostatic precipitator Wet scrubber Process modification --forming air recirculation
Curing	High velocity air filter Incinerator Process modification --special binder formulations
Cooling	High velocity air filter
Forming + curing	Wet electrostatic precipitator
Curing + cooling	High velocity air filter Wet scrubber
Forming + curing + cooling	Wet electrostatic precipitator

4.1.2 Binder Formulation

Changing the binder formulation is reported to be a technique that affects process emissions.[3] The type and/or relative proportions of chemical compounds that make up the binder may be altered to reduce emissions. For example, the volatile constituents in the binder may be reduced, thereby reducing emissions. Binder formula modifications have an effect on both the manufacturing process and on the product properties. Therefore, manufacturers are unable to select a binder formulation solely for its effect on emissions.

4.1.3 Water Sprays

Water overspray rings installed on the forming spinners may affect emissions. These sprays are primarily installed to cool the glass fibers before the binder is applied. This cooling is reported to reduce the amount of binder that volatilizes on the hot glass.[4]

4.2 WET ELECTROSTATIC PRECIPITATORS

Wet electrostatic precipitators (wet ESP's) are used on effluent gas streams containing sticky, condensible pollutants to reduce particulate emissions. These devices have been used for over 30 years in various industrial applications (e.g., aluminum pot lines and carbon anode baking furnaces) to control particulate emissions.[5] The wool fiberglass industry has used wet ESP's for at least 10 years.[6],[7] Seven wet ESP's are currently installed on wool fiberglass lines.

4.2.1 Control System Description

Figure 4-1 presents a diagram of a typical wet ESP that is used in the wool fiberglass industry. Particle collection in an ESP involves three steps: the electrical charging of particles in the gas stream, the collection of the particles on the collection plates or electrodes, and the removal of the collected particulate matter. Electric fields are established by applying a direct-current voltage across a pair of electrodes: a discharge electrode (either a metal rod or plate) and a collection electrode (a metal plate). Figure 4-2 shows a cross-sectional top view of a wet ESP that has metal rod discharge electrodes. Particulate matter and water droplets suspended in the gas stream are electrically charged by passing through the electric field around each discharge

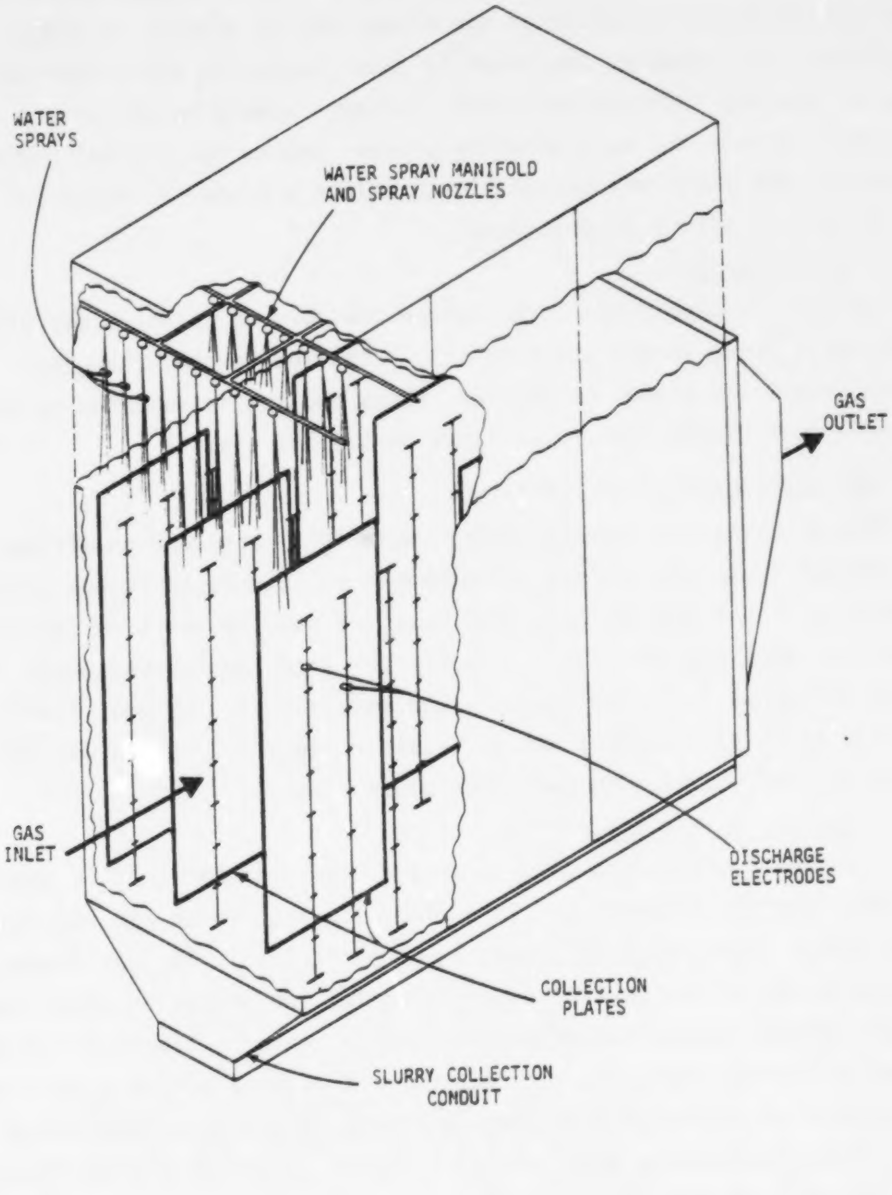

WATER SPRAYS
WATER SPRAY MANIFOLD AND SPRAY NOZZLES
GAS OUTLET
GAS INLET
DISCHARGE ELECTRODES
COLLECTION PLATES
SLURRY COLLECTION CONDUIT

Figure 4-1. Cut-away diagram showing internal construction of a typical wet ESP.

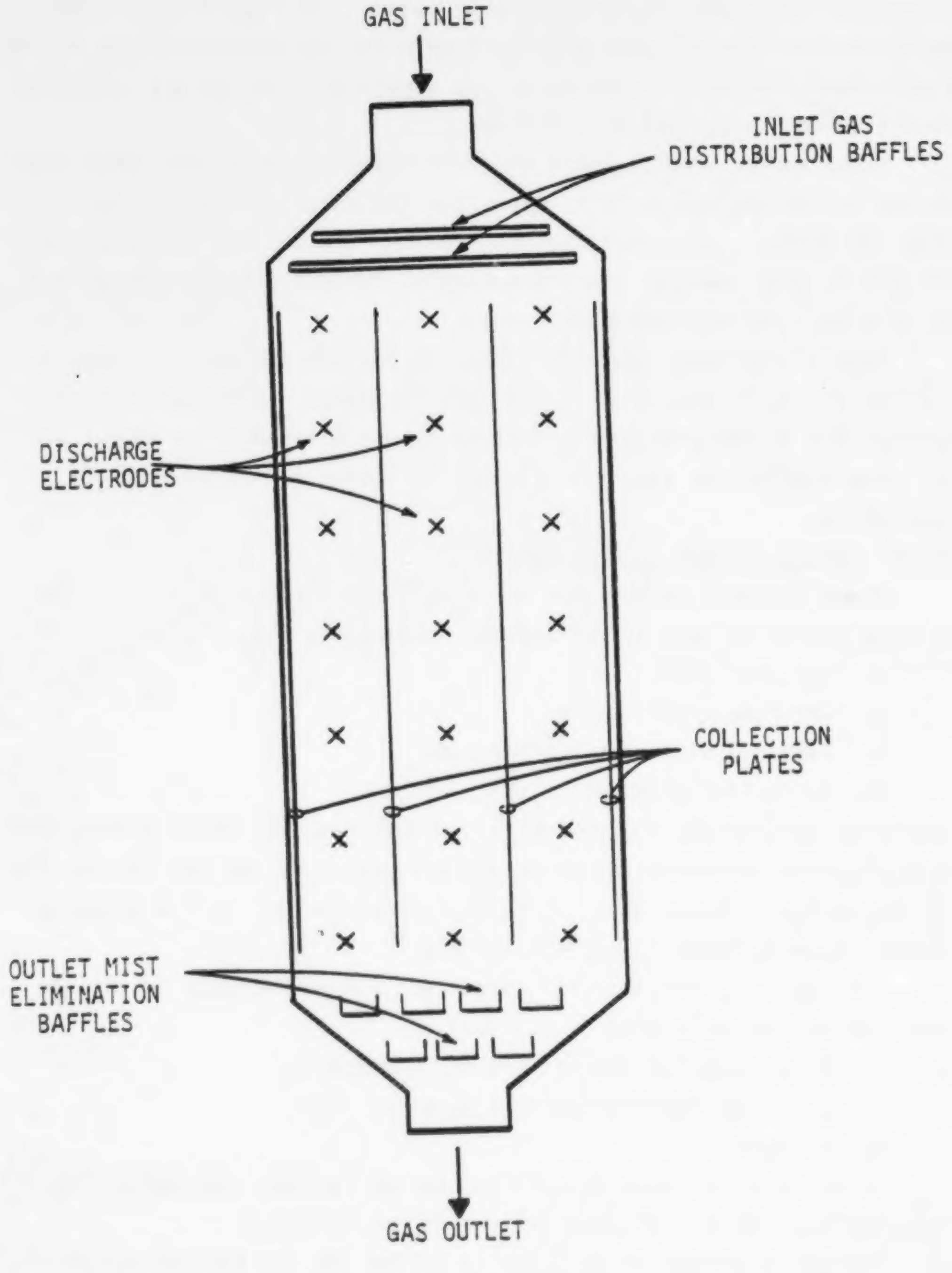

GAS INLET
INLET GAS DISTRIBUTION BAFFLES
DISCHARGE ELECTRODES
COLLECTION PLATES
OUTLET MIST ELIMINATION BAFFLES
GAS OUTLET

Figure 4-2. Cross-sectional top view of a typical wet ESP.

electrode (the negatively charged electrode). The negatively charged particles and droplets then migrate toward the positively charged collection electrodes. The particulate matter is separated from the gas stream by retention on the collection electrode.

Water sprays located above the electrodes create a continuous film on the collection plates that washes the collected particulate matter from the plates. The slurry formed from washing the collection plates is continuously removed from the bottom of the wet ESP and transported to on-site water treatment facilities.

Some of the water droplets formed in the wet ESP are entrained in the gas stream flowing past the collection plates. The last section of the wet ESP is designed to function as a mist eliminator to remove most of these droplets by electrostatic precipitation and/or by inertial separation.

4.2.2 Factors Affecting Performance

A wet ESP must be designed for specific process conditions. The process variables that affect wet ESP performance are:

1. Gas flow rate;
2. Gas flow distribution;
3. Particle size distribution; and
4. Dielectric constant of the particle.

The inlet particulate concentration and the required outlet particulate concentration determine the necessary efficiency of the wet ESP for use in the design calculations.[8] Particle resisitivity is not a property affecting performance in wet ESP systems.[9]

The design parameters that affect wet ESP performance and ensure that the design efficiency is achieved are:

1. Plate area (of the collecting electrodes);
2. Electrode spacing and configuration; and
3. Voltage.

In addition to these process and design factors, the water flow rate and quality will also affect wet ESP performance.

The gas flow rate is critical in sizing the wet ESP collection plate area. Proper design of the ESP (e.g., size of each compartment and the number of compartments) ensures adequate time for the particles to migrate to a collection electrode. Operation at flow rates in excess of the design flow rate will reduce the residence time for charging and collecting the particles and may cause an increase in outlet emissions.[10] In contrast, operation with reduced air flows will result in increased particulate removal efficiency. Therefore, wet ESP's should be designed to accomodate the maximum air flow expected from the production process.

In sizing a wet ESP, the total collection area of the plates must be increased as the fraction of small particles increases. Due to the nature of the gas stream (saturated with water) and particulate matter (sticky), particle size data cannot be obtained for wool fiberglass emission sources. To account for particle size for a new installation, vendors must base the design of a wet ESP on their experience in the wool fiberglass industry and in other industries with similar emission characteristics (e.g., carbon anode baking). This experience has been gained from pilot- and full-scale installations.[11]

The required particle charging time increases with decreasing particle dielectric constant. (A perfect insulator has a dielectric constant of 1, compared to 6.6 for phenol-formaldehyde resin and 78 for pure water.)[12] Therefore, the size of the wet ESP must be sufficient to ensure adequate particle charging time.

The specific collection area (SCA) is defined as the ratio of the total plate area (A) to the gas flow rate (Q). For a given application, collection efficiency improves as SCA increases. However, the ESP also becomes larger and consequently more expensive as the SCA is increased.[13]

The collecting surface area and gas flow rate have been specifically related to the overall collection efficiency through the Deutsch-Anderson equation, which is used to estimate plate area:[14]

$$\eta = 1 - \exp(-wA/Q)$$

where: η = collection efficiency

w = precipitation rate parameter

A = plate area

Q = volumetric gas flow rate

This equation shows that ESP collection efficiency increases with increasing plate area relative to the gas flow rate and with increasing values of the precipitation rate parameter. The precipitation rate parameter is a performance parameter that relates gas flow rate, collection plate area, and particle capture efficiency. This parameter is a function of the physical properties of the emissions (e.g., particle size distribution) and wet ESP design parameters (e.g., electrode arrangement). The precipitation rate parameter is determined by tests on pilot units and/or by operation of a wet ESP on similar emission sources.

The electrode type, plate spacing, height, and length influence the electrostatic forces exerted on the particles and, thus, affect the collection efficiency.

The voltage applied to the ESP electrodes must be sufficient to ensure an adequate electric field strength for charging the particles while minimizing problems of sparking.[15] One vendor of wet ESP's used in the wool fiberglass industry provides units with automatic voltage controls that determine the optimum applied voltage for variable particle concentrations entering the unit.[16]

The gas stream should be saturated with water vapor to prevent evaporation of the collection plate wash water, which could result in dry zones on the wet ESP internals.[17] These dry areas may be fouled with particulate matter, thus reducing collection efficiency.[18] Water to maintain saturation can be added to the gas stream by spray towers, low pressure drop scrubbers, or spray nozzles in the ducts upstream of the wet ESP and/or in the inlet section of the wet ESP. Saturation of the gas stream also lowers the gas temperature and the total gas volume to be cleaned, thereby reducing the size and cost of the wet ESP. The water flow rate must not be too great, however, or arcing will occur, causing a reduction of the voltage and, thus, a reduction of collection efficiency. Vendors typically optimize water flow rates and spray patterns during the system startup period.[19]

Water quality is important to wet ESP performance.[20,21] The water sprayed into the wet ESP and into the gas stream prior to the wet ESP is typically recycled water that contains particles and resin components. Inadequate water treatment will result in excessive particulate matter in the spray water that will plug the spray nozzles and the distribution pipes.[22,23] To ensure proper wet ESP operation, vendors of units used in the wool fiberglass industry recommend limiting total solids in the water to approximately 1 to 2 percent.[24,25]

The presence of dust or moisture in an insulator compartment can lead to arcing, failure of the insulator, and shorting out of the electric field, all of which affect ESP performance. Therefore, vendors provide heated, pressurized compartments to keep the insulators clean and dry.[26]

4.3 WET SCRUBBERS

Wet scrubbers have two different functions in the wool fiberglass industry. High pressure drop scrubbers are used as primary control devices to capture particulate emissions. In addition, low pressure drop scrubbers are used upstream of other control equipment to collect large particles and to cool and saturate the gas stream. Cooling also causes some of the hydrocarbons in the gas to condense, thus forming liquid droplets which can then be removed by subsequent particulate control equipment.

4.3.1 Control System Description

Orifice scrubbers and venturi scrubbers are used as emissions control devices in the wool fiberglass industry. A cross-sectional view of a typical orifice scrubber that is used on wool fiberglass lines is shown in Figure 4-3. A cross-sectional view of a typical venturi scrubber is shown in Figure 4-4. The operating principles in both orifice and venturi scrubbers are the same. Wet scrubbers in the wool fiberglass industry use water as a scrubbing liquid. The scrubbing water and gas stream flow through a chamber designed to cause collisions between the suspended particulate matter and water droplets generated by the turbulent gas flow. (These collisions occur because the gas stream with the suspended particulate matter moves at a high velocity relative to the water droplets.) As a result of these collisions, the particles become suspended in the water droplets. The water droplets laden with particulate matter are then separated from the gas stream by an inertial separator, which sharply changes the gas flow direction and causes the suspended water droplets to impinge on a collecting baffle or wall.

For a typical wet scrubber, the collection efficiency increases as the turbulence and the difference in velocity between suspended particles and water droplets increase. In both the orifice scrubber and the

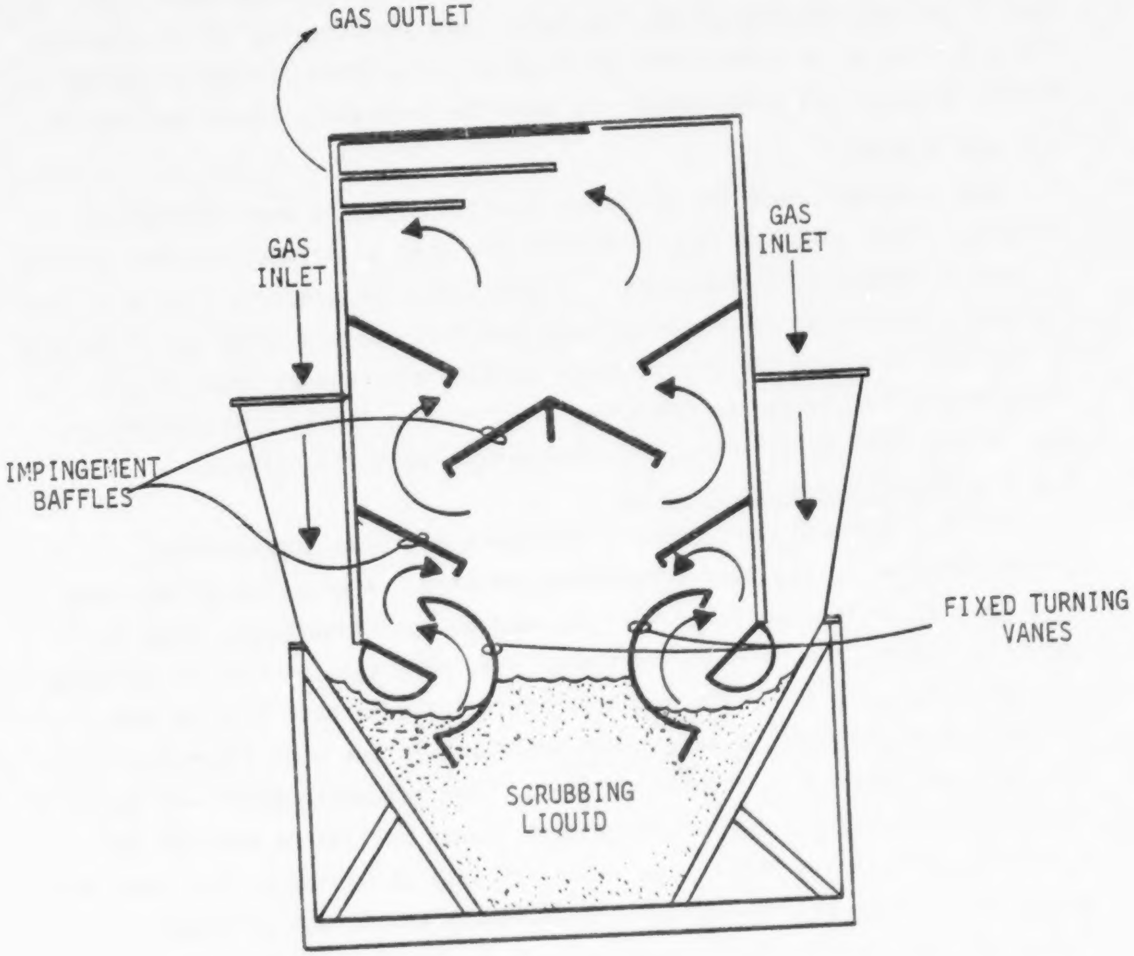

GAS OUTLET
GAS INLET
GAS INLET
IMPINGEMENT BAFFLES
FIXED TURNING VANES
SCRUBBING LIQUID

Figure 4-3. Cross-sectional side view of a typical orifice scrubber.

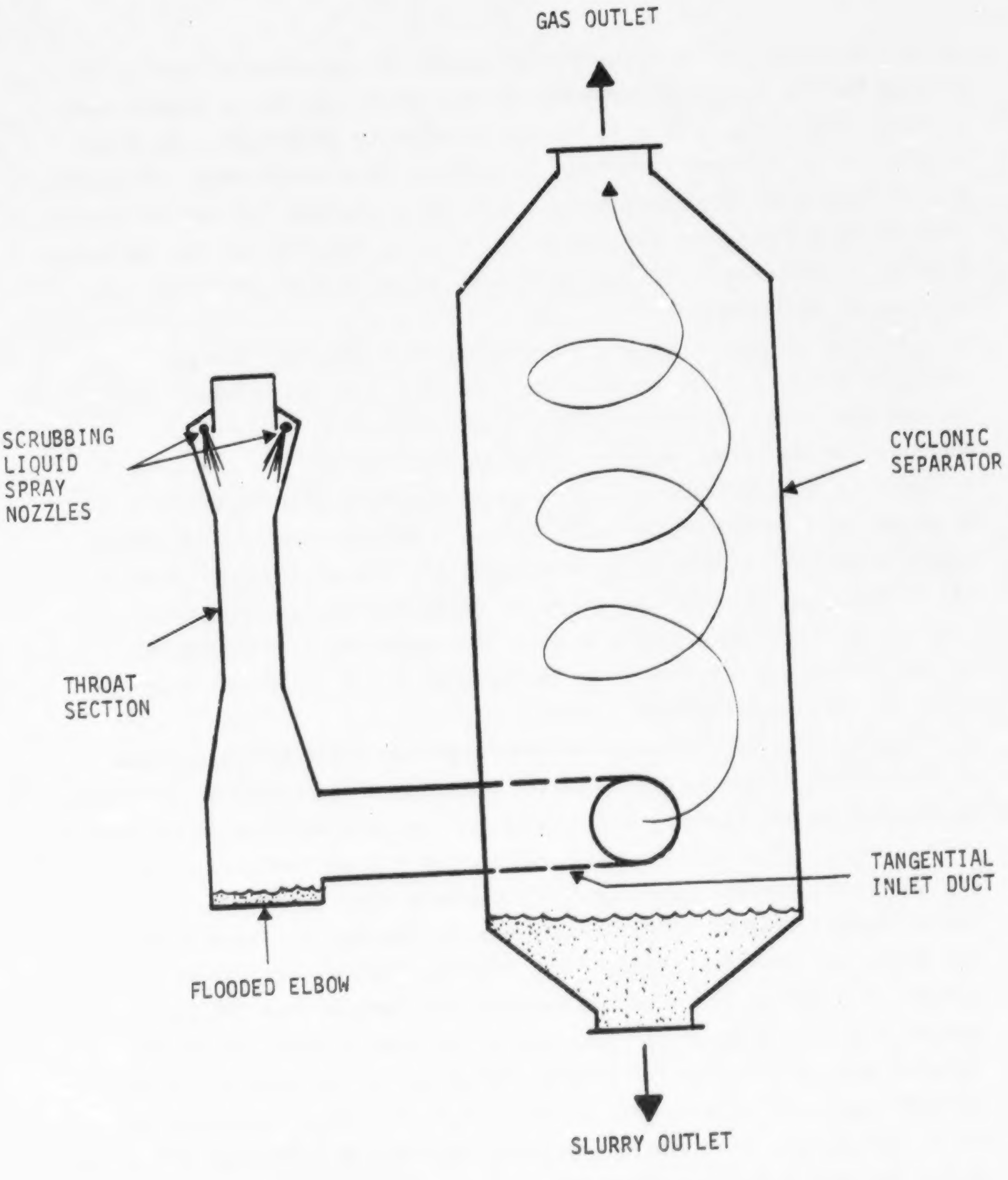

GAS OUTLET
SCRUBBING LIQUID SPRAY NOZZLES
CYCLONIC SEPARATOR
THROAT SECTION
TANGENTIAL INLET DUCT
FLOODED ELBOW
SLURRY OUTLET

Figure 4-4. Cross-sectional side view of a typical venturi scrubber.

venturi scrubber, the velocity and turbulence are generated primarily by forcing the gas through a flow restriction, which requires an expenditure of energy and causes a drop in the static pressure of the gas. As shown in Figure 4-5, scrubber efficiency increases with pressure drop. Therefore, the pressure drop of a scrubber is a convenient indicator of the efficiency that can be achieved and the energy that will be required for its operation. Figure 4-5 shows the relationships between pressure drop, particle size, and removal efficiency.

Orifice scrubber. In orifice scrubbers (Figure 4-3), the gas stream is constricted to increase its velocity. The gas stream flows through the outlet of the converging flow channel that is partially submerged in the scrubbing water. The vessel shape and the curved face of the turning vanes cause the gas flow to force the water surface downward, thus agitating the water surface. The gas flow is then turned upward by another turning vane. The turbulent flow of the high velocity gas stream entrains large quantities of water droplets which collide with the suspended particulate matter. The entrained particulate matter and water droplets are removed by impingement on mist eliminators or the walls of the scrubber outlet sections.

Venturi scrubber. Venturi scrubbers utilize water sprays upstream of a converging and diverging "throat" (venturi) (Figure 4-4) to introduce water into the gas stream. Water under low pressure may also be introduced at the throat. The velocity and turbulence of the gas increase as it approaches the throat. The high gas turbulence atomizes the liquid into small droplets (the higher the pressure drop, the smaller the droplet) and increases interaction between the droplets and the particulate matter. The wetted particles and droplets are removed from the gas stream in a cyclone separator that may be followed by other mechanical means of mist elimination.[27] Several variations of the standard venturi scrubber have been developed to allow the venturi throat dimensions to be changed as gas flow rates change, thus maintaining a constant efficiency.

4.3.2 Factors Affecting Performance

Orifice and venturi wet scrubbers must be designed for the specific process conditions encountered. Those process conditions that affect performance are:

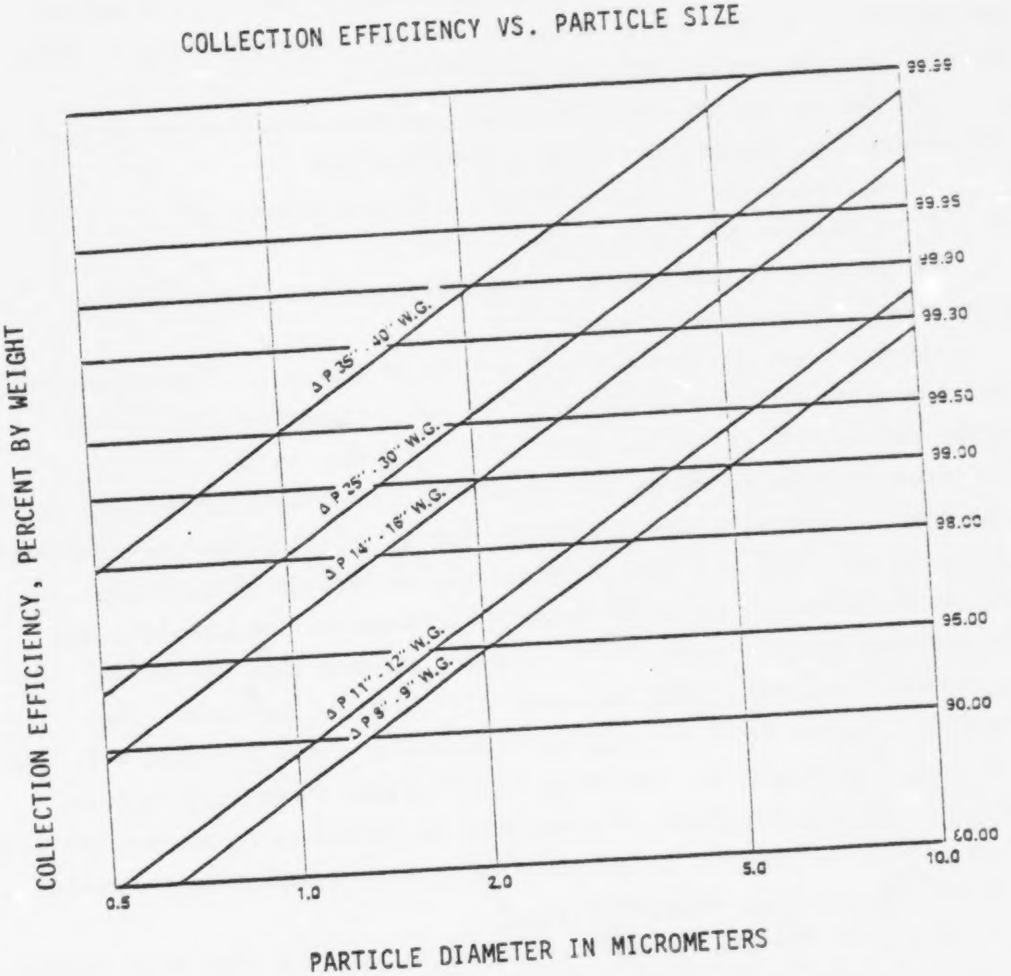


Figure 4-5. Venturi scrubber comparative fractional efficiency curves.[28]

1. Gas flow rate,
2. Particle size distribution, and
3. Inlet particle concentration.

Wet scrubbers are designed for a maximum load and particulate matter concentration so that outlet emissions during low load conditions will be less than the design emission rate.[29]

The design factors that affect orifice and venturi scrubber performance and ensure that design efficiency is achieved are:

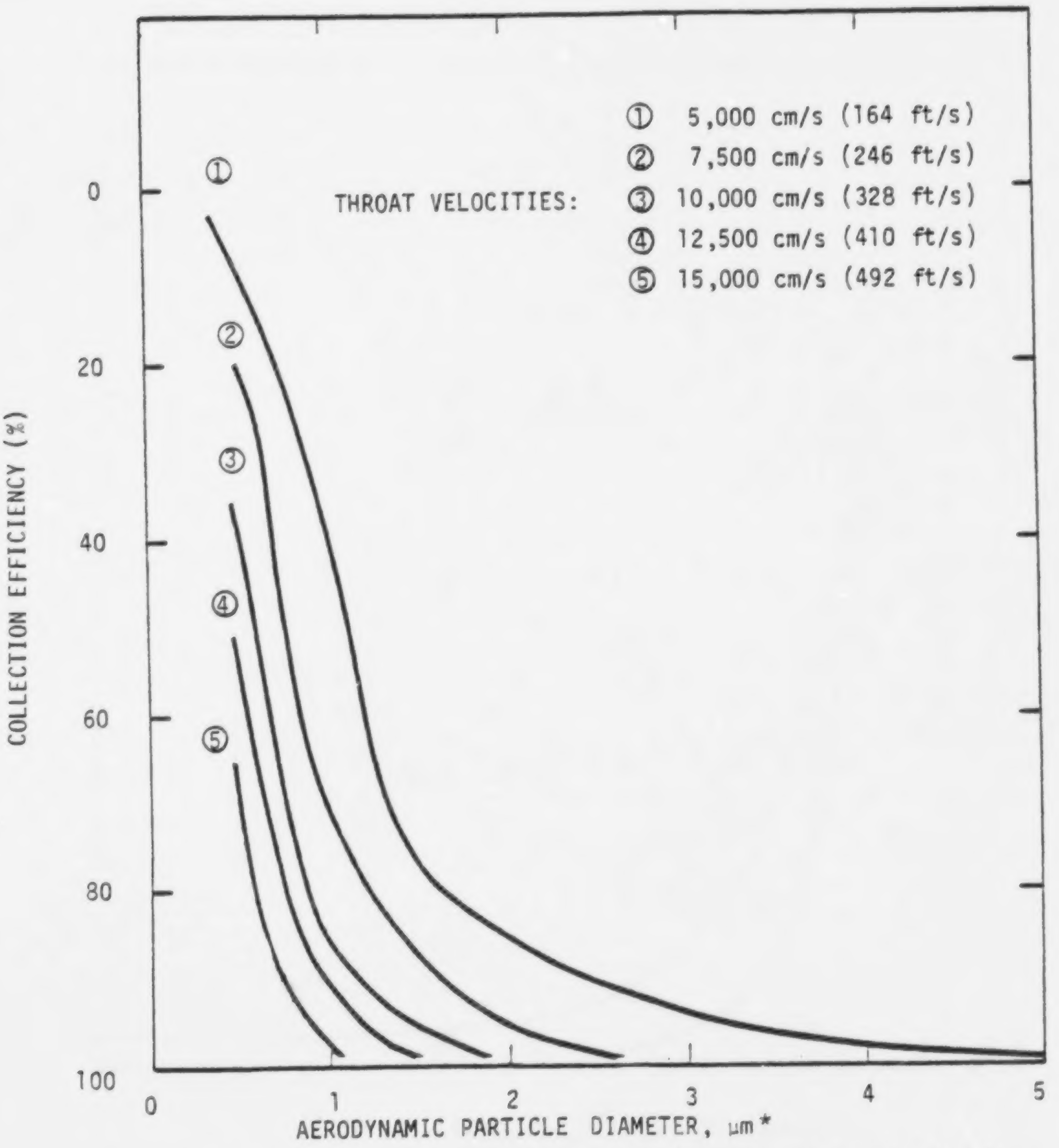
1. Gas velocity in the orifice or venturi throat; and
2. Liquid-to-gas (L/G) ratio.

In addition to these process and design factors, water quality will also affect scrubber performance.

The gas flow rate determines the size of the unit. The gas velocity past the water droplets is the major factor influencing particulate matter removal.[30] Collection efficiency increases as the velocity in the throat/orifice increases.[31] Theoretical efficiency curves showing the effect of variable throat velocity for a typical venturi are presented in Figure 4-6. The L/G ratio only affects collection efficiency at low L/G ratios where collection efficiency increases as the L/G ratio and the pressure drop increase.[32-34] However, at very high L/G ratios, liquid may flood the system and cause efficiency to decrease. The effect of the L/G ratio in a typical venturi is shown in Figure 4-7. As particles become smaller, the relative difference in velocity between the particles and the water droplets must be increased to achieve collision. (Small particles tend to follow gas flow streams around droplets rather than collide with the water droplets.)

To account for their inability to obtain particle size data, vendors design scrubbers based on experience in the industry, prototype testing, or experience with similar emissions sources.[37]

Wet scrubber performance is affected by water quality. Suspended solids in the water coat the inside of ducts and pipes, spray nozzles, and/or internal parts of the scrubber, eventually causing them to become plugged.[38] Wastewater from orifice or venturi scrubbers is typically reused in the manufacturing process (e.g., in the binder formulation) or



*The aerodynamic particle diameter is the diameter of a unit density sphere having the same aerodynamic characteristics as the actual particle.

Figure 4-6. Theoretical efficiency curve for a venturi scrubber illustrating effect of throat velocity.[35]

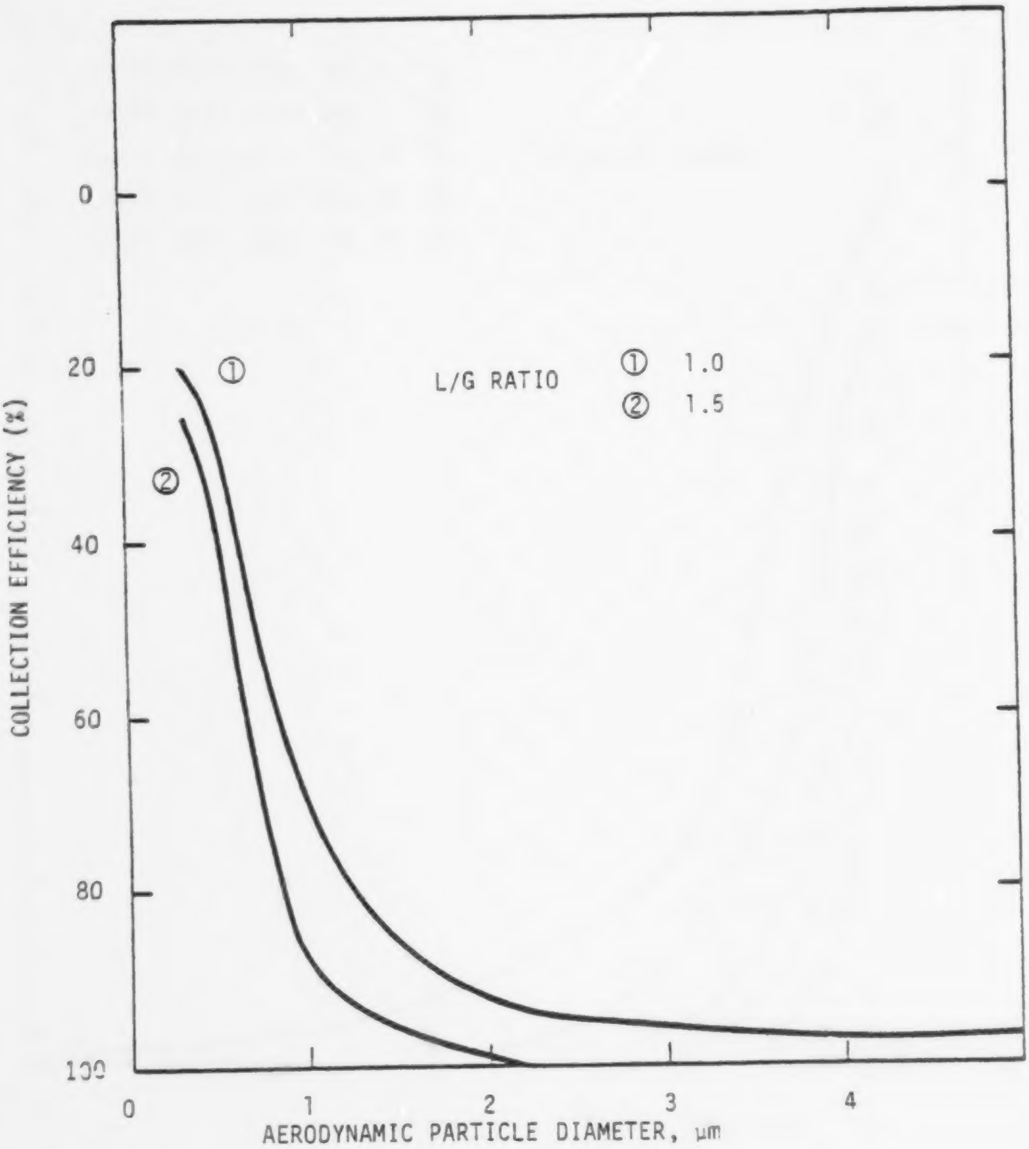


Figure 4-7. Theoretical efficiency curve for venturi scrubber illustrating effect of liquid-to-gas ratios.[36]

in the control device. Solids are removed from the water by settling and screening processes.

4.4 HIGH VELOCITY AIR FILTERS

4.4.1 Control System Description

High velocity air filters (HVAF's) collect particulate matter by the impaction of particles on a glass fiber mat. They are used at some rotary spin (RS) and flame attenuation (FA) wool fiberglass plants to control emissions on curing operations or combined curing and cooling operations. Figure 4-8 illustrates an HVAF unit typical of that used in the wool fiberglass industry. The HVAF includes a motor-driven fan and a rotating drum filter section. The vendor-provided HVAF unit includes a mist eliminator to capture aerosols or droplets that escape from the filter mat.[39,40] The fiberglass filter mat is made specifically for use in the HVAF. The vendor recommends a mat that has a specified, constant thickness (0.64 centimeter [cm], 0.25 inch [in.]) and density (0.2 kilograms per cubic meter [kg/m^3], 0.04 pound per cubic foot [lb/ft^3]).[41]

The emissions from wool fiberglass operations contain both solid and condensible particulate matter; some of these emissions condense when the gas is cooled and form particulate matter (aerosols) that is also filtered out by the HVAF.[42] Cooling of the gas stream is accomplished using evaporative cooling chambers with air-atomized or high pressure water sprays.[43] The low viscosity aerosols migrate through the mat and are then thrown off the mat as larger droplets to be removed from the gas stream by inertial separation in the mist eliminator. The solid particulate matter and the more viscous aerosols remain in the mat. When the pressure drop across the mat increases to a predetermined level, the mat is advanced to expose fresh filter media to the gas stream.

4.4.2 Factors Affecting Performance

Given a specific filter media, the two parameters that affect the collection efficiency of the HVAF are the filter face velocity and the inlet gas temperature.

Filter face velocity is defined as the ratio of the flow rate of the gas volume filtered to the area of the exposed filter media. A high

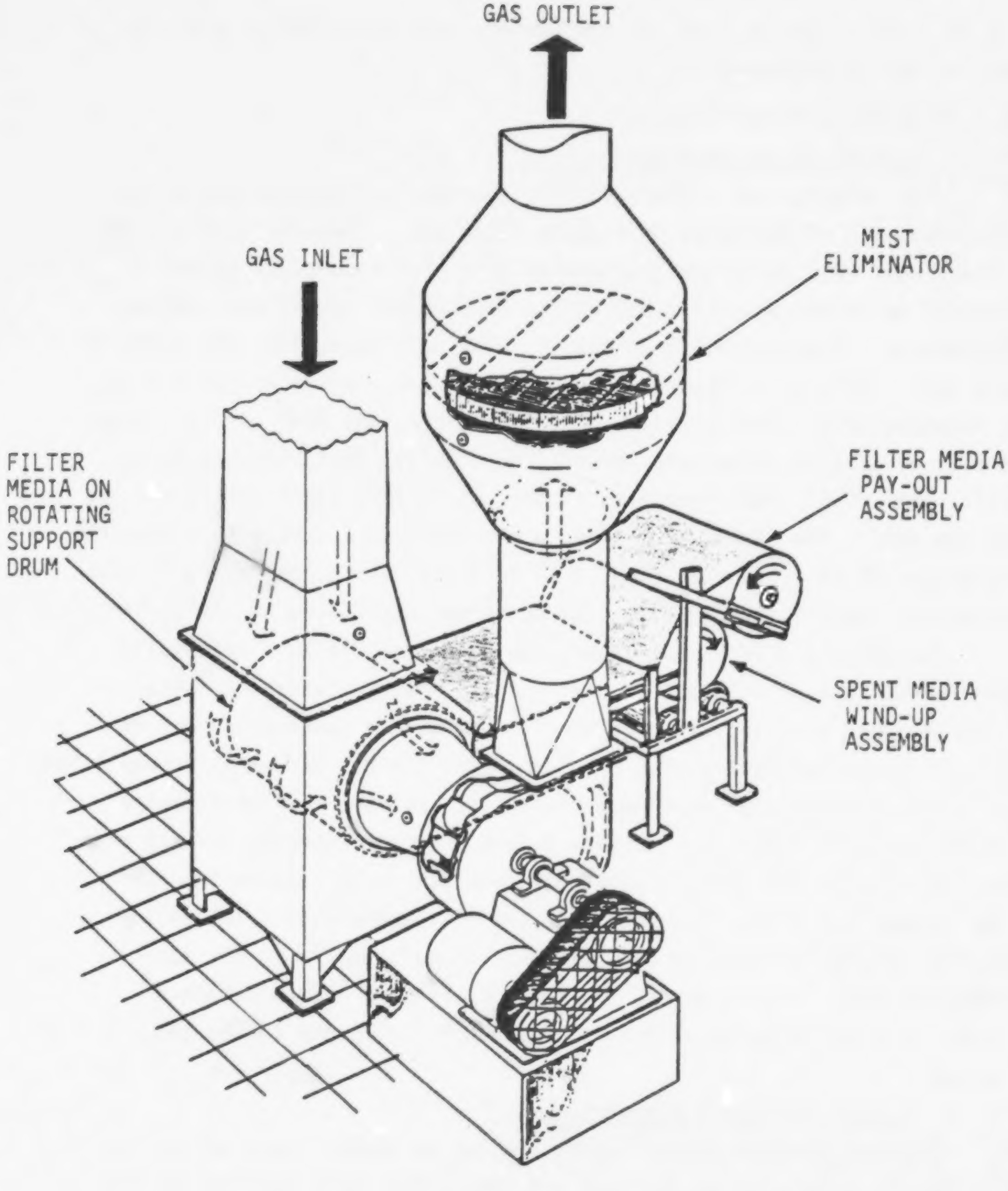

GAS OUTLET
GAS INLET
MIST ELIMINATOR
FILTER MEDIA ON ROTATING SUPPORT DRUM
FILTER MEDIA PAY-OUT ASSEMBLY
SPENT MEDIA WIND-UP ASSEMBLY

Figure 4-8. High velocity air filter.[44]

filter face velocity is necessary to attain a high collection efficiency.[45] As shown in Figure 4-9, within a certain range, an increase in filter face velocity increases removal efficiency by increasing the particle momentum. Above this range, efficiency levels off. Increased momentum increases the probability that a particle will impact on the fibers of the mat rather than remain entrained in the gas stream. Energy consumption also increases as filter face velocity increases.

To maximize collection efficiency, the inlet temperature of the gas must be below the condensation point of the condensible compounds in the stream. The vendor recommends cooling the gas stream, before it enters the HVAF, to at least 60°C (140°F) to effect condensation.[46]

The solid particles and viscous condensible compounds that collect on the filter mat eventually plug it.[47] Periodically, the filter is advanced to expose fresh media to the exhaust flow. Automatic advance of the filter media may be accomplished at either a predetermined time interval or at a predetermined pressure drop across the filter. The collection efficiency of the filter mat increases as the filter becomes coated and the pressure drop increases. With the time-operated advance, if new material is advanced too soon, a large filter area may be "uncaked" and the collection efficiency will decrease. The pressure-actuated advance system operates by sensing differential pressure across the mat and advancing the filter approximately one inch at a time until a preset lower pressure is measured.

4.5 THERMAL INCINERATORS

A thermal incinerator vaporizes and oxidizes combustible material. In wool fiberglass manufacturing, thermal incinerators are used to reduce emissions from curing operations.

In the wool fiberglass industry, thermal incinerators are operated in two temperature ranges. Some thermal incinerators are operated at approximately 700°C (1300°F) with a residence time of 0.5 seconds to destroy all organic species (Figure 4-10).[49] Others (afterburners) are operated at about 300°C (600°F), which is not high enough to destroy the solid and liquid particulate matter. However, this temperature is high

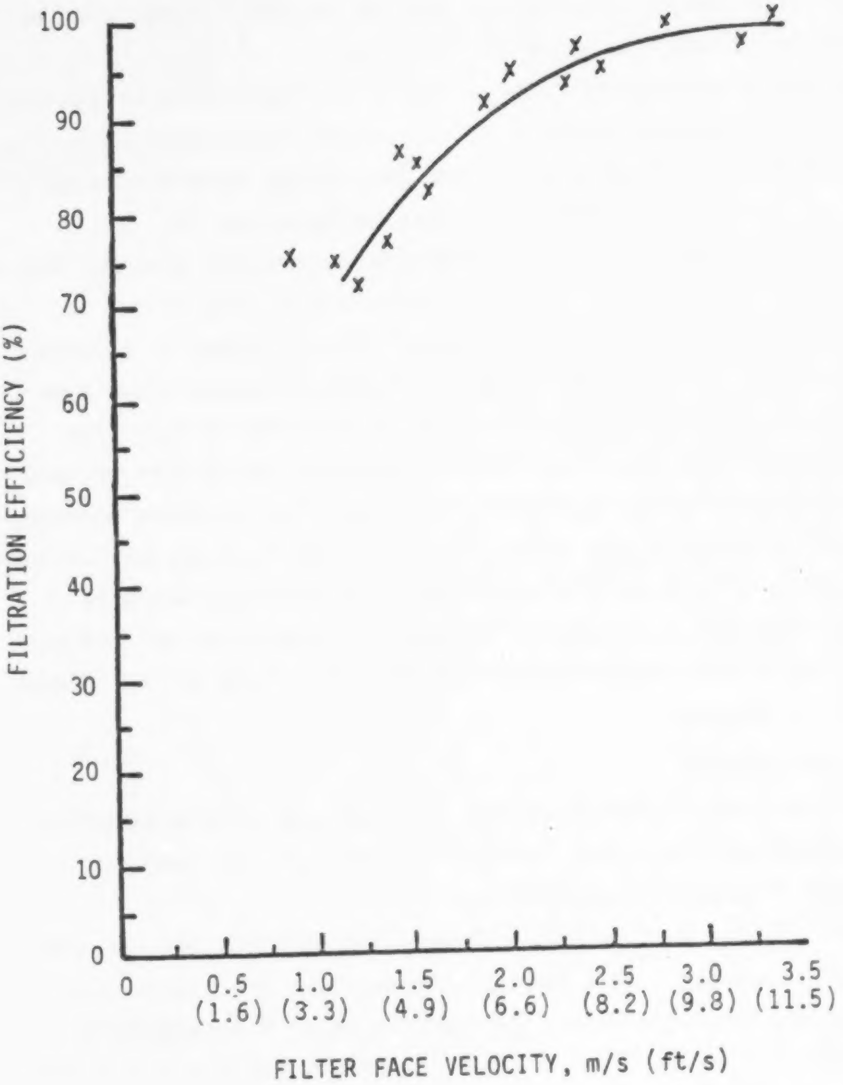


Figure 4-9. HVAF filter media filtration efficiency as a function of filter face velocity.[48]

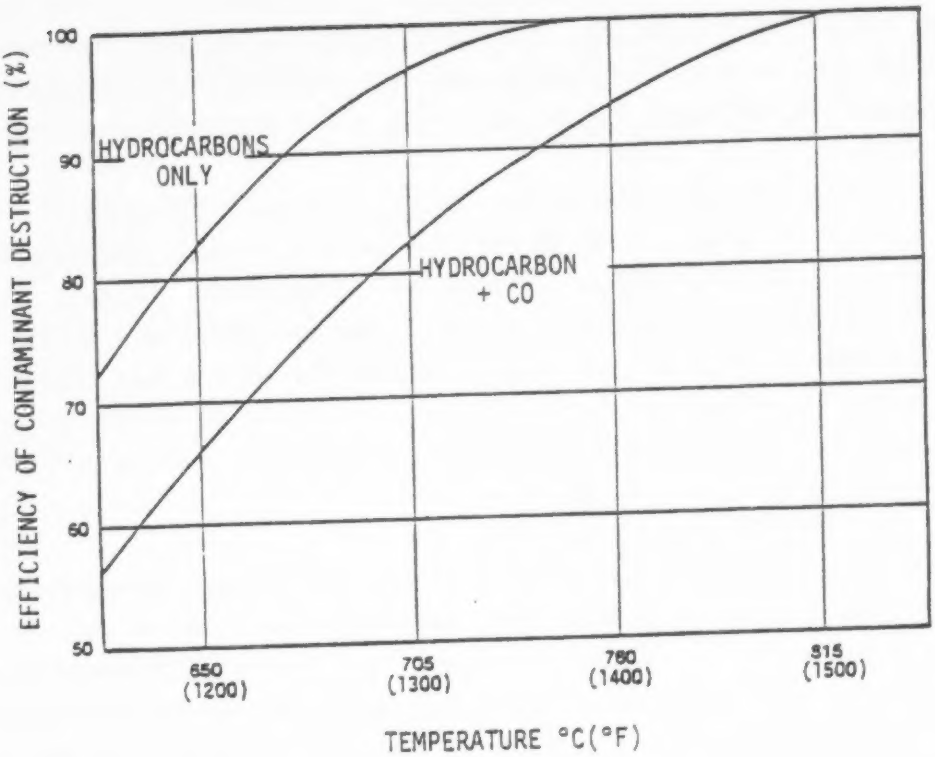


Figure 4-10. Typical effect of operating temperature on effectiveness of thermal incinerator for destruction of hydrocarbons and carbon monoxide.[54]

enough to vaporize the liquid particulate matter, which will reduce the opacity of the emissions leaving the stack.[50,51]

4.5.1 Control System Description

Thermal incinerators are used to control emissions comprised of gases or particles that are combustible or that will thermally decompose. The combustible materials are converted to carbon dioxide (CO_2) and water. In the wool fiberglass industry, thermal incinerators require auxiliary fuel to achieve effective combustion because the concentration of combustible pollutants in the gas stream is too dilute to sustain combustion.[52]

As used in the wool fiberglass industry, thermal incinerators consist of a refractory-lined chamber, one or more burners, temperature controls, and safety equipment. Figure 4-11 illustrates a typical thermal incinerator. The steps involved in the combustion of a dilute fume are shown in Figure 4-12. The contaminated gases are delivered to the incinerator, mixed thoroughly with the fuel by the burner flames in the upstream part of the unit, and passed through the remaining part of the chamber to complete combustion.

4.5.2 Factors Affecting Performance

The important variables affecting particulate matter combustion in incinerators are reaction temperature, residence time, and reactant mixing (turbulence).[53] As shown in Figure 4-13, the reaction temperature and residence time required to destroy particulate matter are interdependent; a higher temperature allows use of a shorter residence time and vice versa.

Temperatures of 650° to 760°C (1200° to 1500°F) are sufficient to obtain nearly complete oxidation of most organic substances in 0.1 to 0.3 seconds, although destruction of some organic compounds, such as methane, and the oxidation of carbon monoxide (CO) to CO_2 require longer residence times and higher temperatures.[58]

The principal requirement regarding temperature is that the auto-ignition temperature of all species to be burned must be exceeded by approximately 100 to 200 Celsius degrees (180 to 360 Farenheit degrees).[59] This allows for a margin of error to account for nonideal combustion conditions. Operation at less than the auto-ignition temperature means

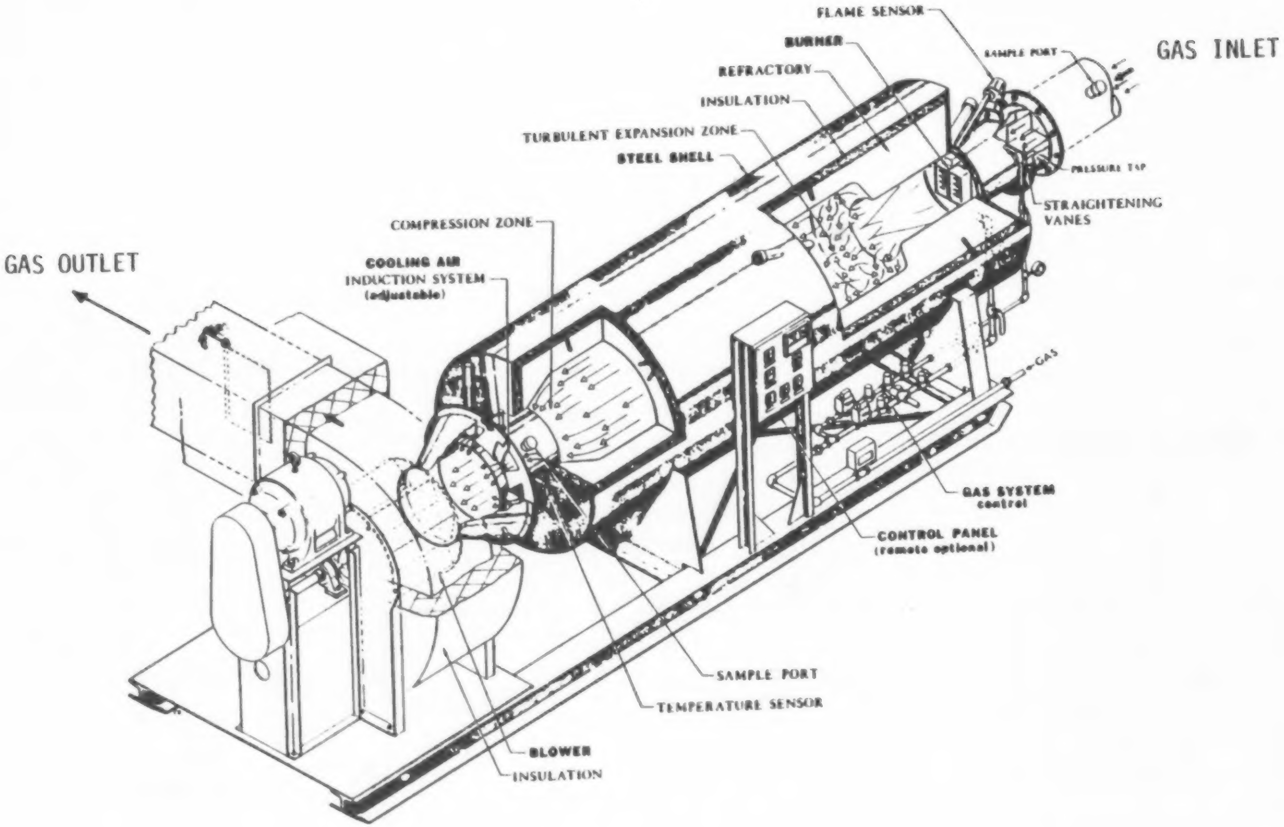

FLAME SENSOR
BURNER
SAMPLE PORT
GAS INLET
REFRACTORY
INSULATION
TURBULENT EXPANSION ZONE
STEEL SHELL
PRESSURE TAP
STRAIGHTENING VANES
COMPRESSION ZONE
GAS OUTLET
COOLING AIR INDUCTION SYSTEM (adjustable)
GAS
GAS SYSTEM control
CONTROL PANEL (remote optional)
SAMPLE PORT
TEMPERATURE SENSOR
BLOWER
INSULATION

Figure 4-11. Thermal incinerator.[55]

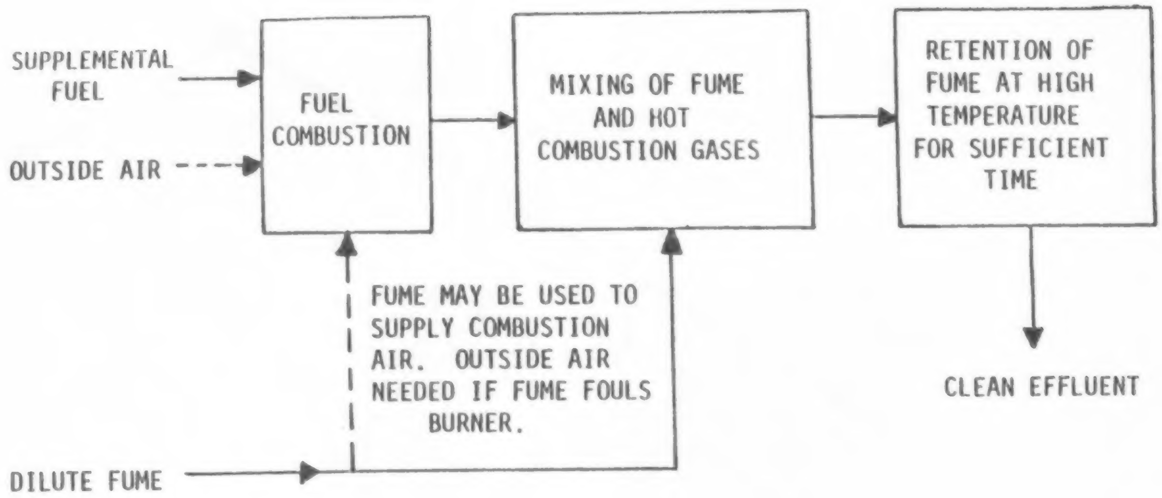

SUPPLEMENTAL FUEL
OUTSIDE AIR
DILUTE FUME
FUEL COMBUSTION
MIXING OF FUME AND HOT COMBUSTION GASES
RETENTION OF FUME AT HIGH TEMPERATURE FOR SUFFICIENT TIME
CLEAN EFFLUENT
FUME MAY BE USED TO SUPPLY COMBUSTION AIR. OUTSIDE AIR NEEDED IF FUME FOULS BURNER.

Figure 4-12. Steps required for successful incineration of dilute fumes.[56]

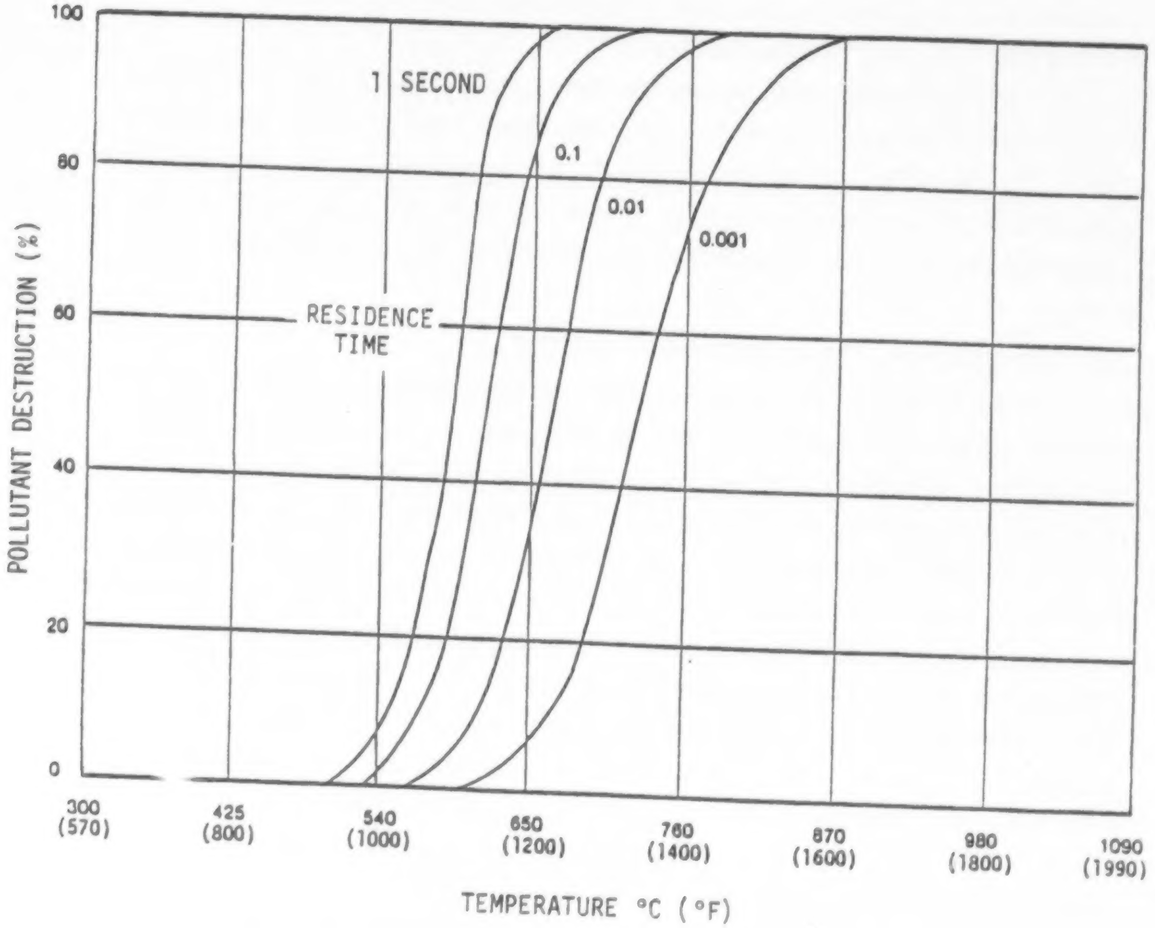


Figure 4-13. Coupled effects of time and temperature on rate of pollutant oxidation by thermal incineration.[57]

that combustion reactions are not initiated; the particles are merely heated, and some volatilization may occur. Stack opacities may be reduced, but recondensation of particulate matter may occur downwind.[60] The auto-ignition temperatures for formaldehyde and phenol, which are components of the fume in the wool fiberglass industry, are 300° and 717°C (570° and 1322°F), respectively.[61,62]

The effectiveness with which the fume is mixed with the combustion products has a major influence on the residence time for a given temperature. If a portion of the gas stream is not mixed well with the combustion gases, that portion may not remain in the incinerator long enough to be heated to the required temperature or for the oxidation reaction to take place.

4.6 PERFORMANCE OF EMISSION CONTROL SYSTEMS

The performance of various control systems that were tested to develop a data base for this study is discussed in this section. The data base on controlled emissions is based on nine tests conducted on seven wool fiberglass manufacturing lines, which include five RS and two FA lines. Some test data have been excluded from the data base because of process upset conditions, control equipment malfunctions, and procedural discrepancies with EPA test methods. The excluded test data and the reasons for exclusion are presented in Appendix C. Emission data from tests performed by local agencies or plant owners are not reported because the test methods used to develop such data are not comparable with the test methods used in this study. However, some data (e.g., volumetric flow rates) from these reports were used to broaden the data base for model plant development (see Chapter 6).

The lines tested include small, medium, and large RS lines and small FA lines. For each test, the operating conditions of the process and control device are, unless otherwise noted, representative of normal plant operating conditions.[63-69] The production rates of the seven lines during testing ranged from 455 to 5,900 kilograms per hour (kg/h) (1,000 to 13,000 pounds per hour [lb/h]) or 1,820 to 47,200 megagrams per year (Mg/yr) (4,000 to 52,000 tons/yr) and from 68 to 100 percent of design capacity. Separate tests were performed during the production of

R-11 building insulation (BI), R-19 BI, ductboard (DB), and heavy density insulation (HDI). These products have densities ranging from 8.2 to 118.5 kilograms per cubic meter (kg/m^3) (0.5 to 7.4 pounds per cubic foot [lb/ft^3]) and loss on ignition (LOI) values ranging from 3.9 to 18 percent. These products were identified by the industry as those that would reflect the range of emissions likely to be generated by wool fiberglass manufacturing operations.[70]

For RS lines, the combinations of operations that were tested were: forming; forming and curing; forming, curing, and cooling; curing; curing and cooling; and cooling. For FA lines, curing and cooling combined and curing alone were tested. The air pollution controls tested on RS lines were: wet ESP's, wet scrubbers, HVAF's, an incinerator, process modifications, and combinations of these controls. On FA lines, the only air pollution controls tested were HVAF's.

Data obtained from the EPA testing program for particulate emissions, phenol, phenolic compounds, and formaldehyde are summarized in Tables 4-2, 4-3, 4-4, and 4-5, respectively.[63-69] The data are presented graphically in Figures 4-14 through 4-17. The test and analysis methodologies may be found in Appendix D. Emissions data for each controlled process are presented in units of mass emissions per unit weight of glass pulled. (The glass pull rate is the total amount of molten glass entering the forming section on one line.) In some cases, the values for the operating conditions are given as a percent of the design values because the actual test values are deemed confidential by industry.

Emissions test results for each control device are discussed in the following sections.

4.6.1 Wet ESP's

The data base contains emissions data from two wet ESP's, one on line A and one on line D. Emission data and specific operating parameters during each test are shown in Table 4-6. The wet ESP on line A controls emissions from forming and curing. It is preceded by low pressure drop scrubbers and water sprays on forming and curing. This wet ESP is designed to use a continuous spray of wash water on the collection plates. The scrubbers and wash water sprays were operating during the test program.

TABLE 4-2. SUMMARY OF CONTROLLED PARTICULATE MATTER EMISSION DATA[a] 63-69

Line/ test	Product[b]	Process type[c]	Forming		Forming and curing		Curing		Curing and cooling		Forming, curing and cooling		Total line emissions		Primary control device
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	
A1	R-11	RS	--	--	3.3	6.5	--	--	--	--	--	--	3.4[d]	6.8	Wet ESP
A2	R-19	RS	--	--	3.9	7.9	--	--	--	--	--	--	4.0[d]	8.1	Wet ESP
A3	DB	RS	--	--	4.8	9.7	--	--	--	--	--	--	4.9[d]	9.9	Wet ESP
B	HDI	RS	--	--	2.0	4.0	0.1	0.2	--	--	--	--	2.0[e]	4.0	Process modification, Incinerator
C	R-11	RS	--	--	--	--	--	--	0.6[f]	1.1	--	--	--	--	HVAF
D	R-11	RS	--	--	--	--	--	--	--	--	1.7[f]	3.3	1.6[f]	3.2	Wet ESP
I	DB	FA	--	--	--	--	--	--	0.6	1.2	--	--	45.0[g]	89.9	HVAF
J	R-11	FA	--	--	--	--	1.2	2.5	--	--	--	--	25.6[g]	51.3	HVAF
L	R-19	RS	1.0	2.0	--	--	--	--	0.3	0.5	--	--	1.3	2.5	Wet scrubber

[a] Average of data runs; total catch results. The test method for particulate matter specifies a Method 5 sampling train with gravimetric analysis of the front-half catch and total organic carbon (TOC) analysis of the impinger (back-half) catch.

[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. HDI = heavy density insulation.

[c] RS = rotary spin. FA = flame attenuation.

[d] Includes uncontrolled cooling emissions.

[e] Excludes cooling emissions.

[f] Includes emissions from asphalt backing process.

[g] Includes uncontrolled forming emissions.

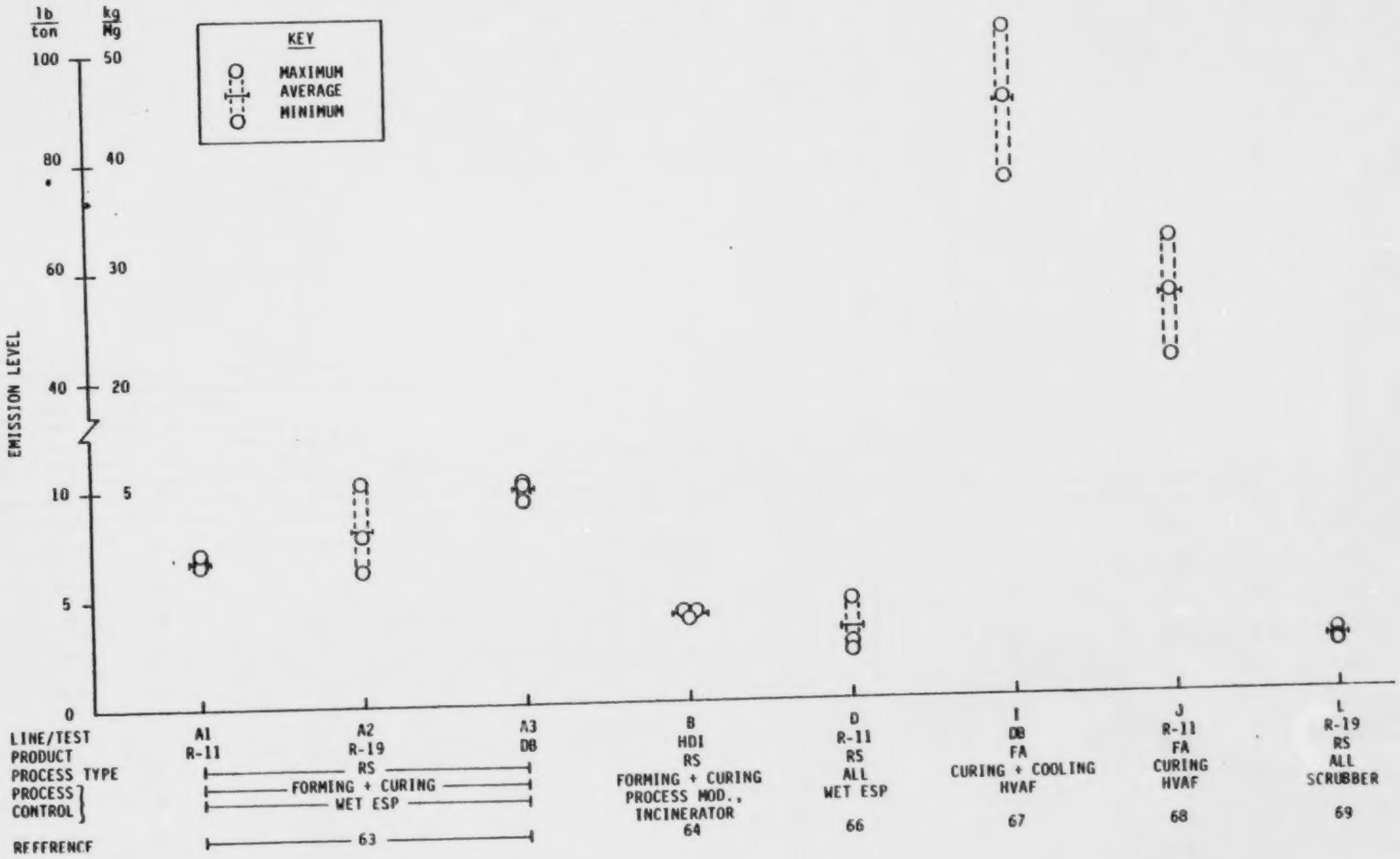


Figure 4-14. Total particulate emissions for controlled wool fiberglass insulation manufacturing lines.

TABLE 4-3. SUMMARY OF CONTROLLED PHENOL EMISSION DATA[a] 63-69

Line/ test	Pro- duct[b]	Process type[c]	Forming		Forming and curing		Curing		Curing and cooling		Forming, curing and cooling		Total line emissions		Primary control device
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	
A1	R-11	RS	--	--	1.0	1.9	--	--	--	--	--	--	1.0[d]	1.9	Wet ESP
A2	R-19	RS	--	--	0.9	1.8	--	--	--	--	--	--	0.9[d]	1.8	Wet ESP
A3	DB	RS	--	--	1.9[d]	3.7	--	--	--	--	--	--	1.9[d]	3.7	Wet ESP
B	HDI	RS	--	--	0.4	0.7	0	0	--	--	--	--	0.4[e]	0.7	Process modification, Incinerator
C	R-11	RS	--	--	--	--	--	--	0.3[f]	0.6	--	--	--	--	HVAF
D	R-11	RS	--	--	--	--	--	--	--	--	0.4[f]	0.8	0.4[f]	0.8	Wet ESP
I	DB	FA	--	--	--	--	--	--	0	0.1	--	--	4.7[g]	9.6	HVAF
J	R-11	FA	--	--	--	--	0.1	0.2	--	--	--	--	1.3[g]	2.7	HVAF
L	R-19	RS	0.4	0.7	--	--	--	--	0.1	0.2	--	--	0.5	0.9	Wet scrubber

[a] Average of data runs; total catch results. The test method for particulate matter specifies a Method 5 sampling train with gravimetric analysis of the front-half catch and total organic carbon (TOC) analysis of the impinger (back-half) catch.

[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. HDI = heavy density insulation.

[c] RS = rotary spin. FA = flame attenuation.

[d] Includes uncontrolled cooling emissions.

[e] Excludes cooling emissions.

[f] Includes emissions from asphalt backing process.

[g] Includes uncontrolled forming emissions.

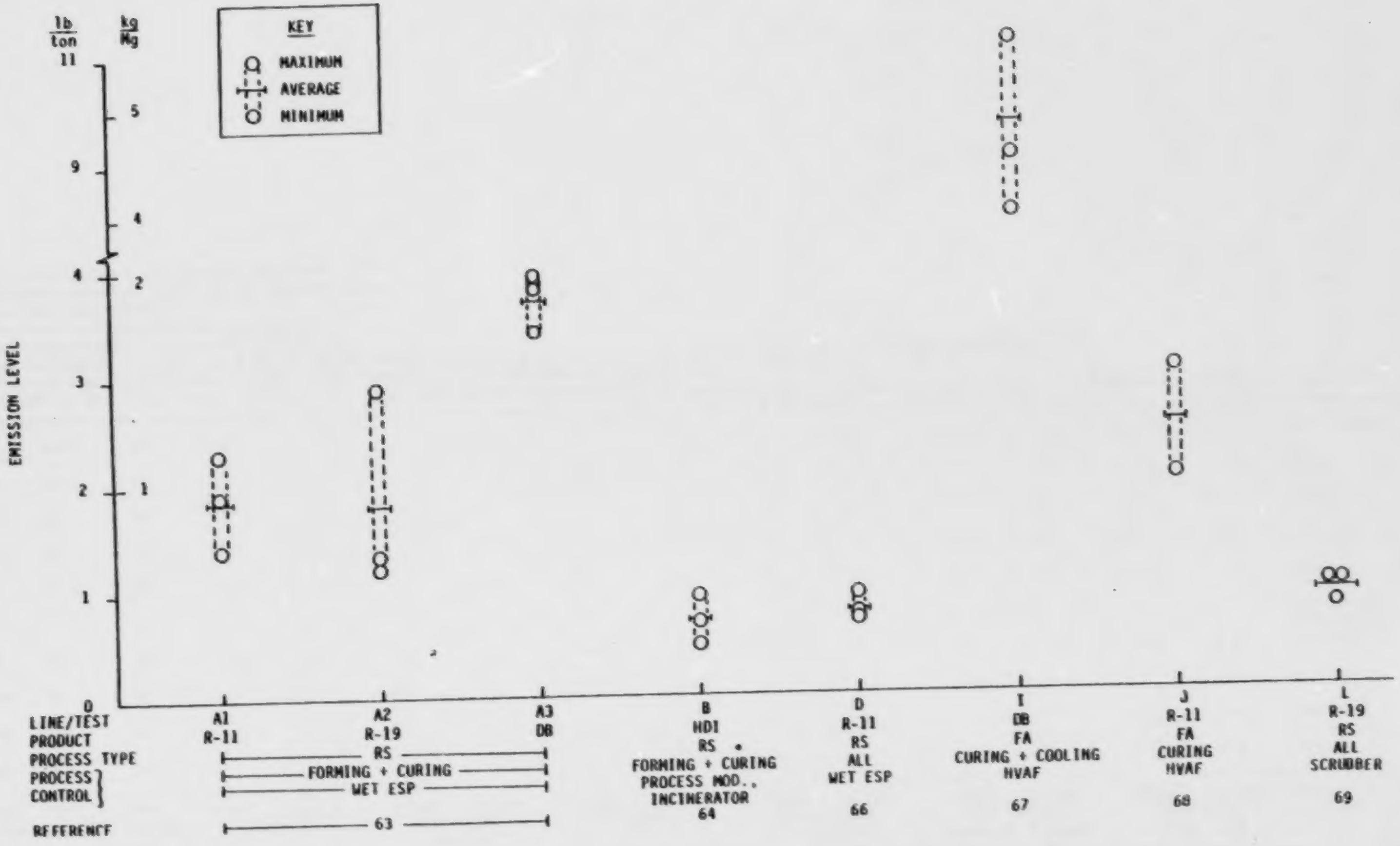


Figure 4-15. Total phenol emissions for controlled wool fiberglass insulation manufacturing lines.

TABLE 4-4. SUMMARY OF CONTROLLED PHENOLIC COMPOUND EMISSION DATA[a] 63-69

Line/ test	Pro- duct[b]	Process type[c]	Forming		Forming and curing		Curing		Curing and cooling		Forming, curing and cooling		Total line emissions		Primary control device
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	
A1	R-11	RS	--	--	1.1	2.2	--	--	--	--	--	--	1.1[d]	2.2	Wet ESP
A2	R-19	RS	--	--	1.2	2.4	--	--	--	--	--	--	1.2[d]	2.4	Wet ESP
A3	DB	RS	--	--	4.1	8.2	--	--	--	--	--	--	4.1[d]	8.2	Wet ESP
B	HDI	RS	--	--	0.5	0.9	0	0	--	--	--	--	0.5[e]	0.9	Process modification, Incinerator
C	R-11	RS	--	--	--	--	--	--	0.2[f]	0.4[f]	--	--	--	--	HVAF
D	R-11	RS	--	--	--	--	--	--	--	--	0.6[f]	1.2	0.6[f]	1.2	Wet ESP
I	DB	FA	--	--	--	--	--	--	0.2	0.5	--	--	12.2[g]	24.6	HVAF
J	R-11	FA	--	--	--	--	0.2	0.4	--	--	--	--	3.5[g]	7.0	HVAF
L	R-19	RS	0.5	1.0	--	--	--	--	0.1	0.2	--	--	0.6	1.2	Wet scrubber

[a] Average of data runs; total catch results. The test method for particulate matter specifies a Method 5 sampling train with gravimetric analysis of the front-half catch and total organic carbon (TOC) analysis of the impinger (back-half) catch.

[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. HDI = heavy density insulation.

[c] RS = rotary spin. FA = flame attenuation.

[d] Includes uncontrolled cooling emissions.

[e] Excludes cooling emissions.

[f] Includes emissions from asphalt backing process.

[g] Includes uncontrolled forming emissions.

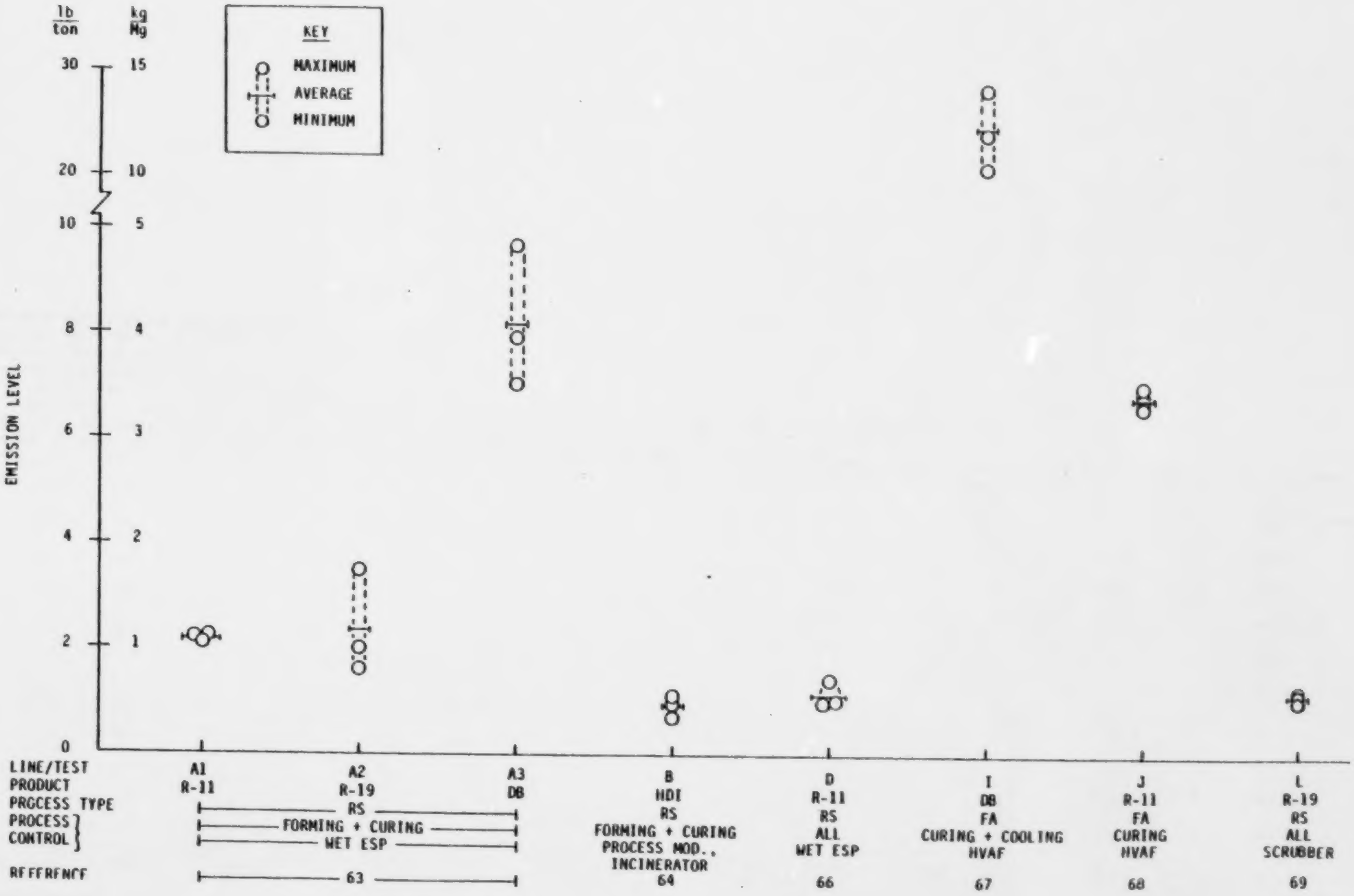


Figure 4-16. Total phenolic compound emissions for controlled wool fiberglass insulation manufacturing lines.

TABLE 4-5. SUMMARY OF CONTROLLED FORMALDEHYDE EMISSION DATA[a] 63-69

Line/ test	Product[b]	Process type[c]	Forming		Forming and curing		Curing		Curing and cooling		Forming, curing and cooling		Total line emissions		Primary control device
			kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	
A1	R-11	RS	--	--	0.2	0.4	--	--	--	--	--	--	0.2[d]	0.4	Wet ESP
A2	R-19	RS	--	--	0.3	0.6	--	--	--	--	--	--	0.3[d]	0.6	Wet ESP
A3	DB	RS	--	--	0.3	0.5	--	--	--	--	--	--	0.3[d]	0.5	Wet ESP
B	HDI	RS	--	--	0.3	0.6	0	0	--	--	--	--	0.3[e]	0.6	Process modification, Incinerator
C	R-11	RS	--	--	--	--	--	--	0.1[f]	0.1	--	--	--	--	HVAF
D	R-11	RS	--	--	--	--	--	--	--	--	0.3[f]	0.5	0.3[f]	0.5	Wet ESP
I	DB	FA	--	--	--	--	--	--	0.4	0.8	--	--	9.8[g]	19.5	HVAF
J	R-11	FA	--	--	--	--	0.5	1.0	--	--	--	--	4.9[g]	9.7	HVAF
L	R-19	RS	0.3	0.6	--	--	--	--	0.1	0.1	--	--	0.4	0.7	Wet scrubber

[a] Average of data runs; total catch results. The test method for particulate matter specifies a Method 5 sampling train with gravimetric analysis of the front-half catch and total organic carbon (TOC) analysis of the impinger (back-half) catch.

[b] DB = ductboard. R-19 = R-19 building insulation. R-11 = R-11 building insulation. HDI = heavy density insulation.

[c] RS = rotary spin. FA = flame attenuation.

[d] Includes uncontrolled cooling emissions.

[e] Excludes cooling emissions.

[f] Includes emissions from asphalt backing process.

[g] Includes uncontrolled forming emissions.

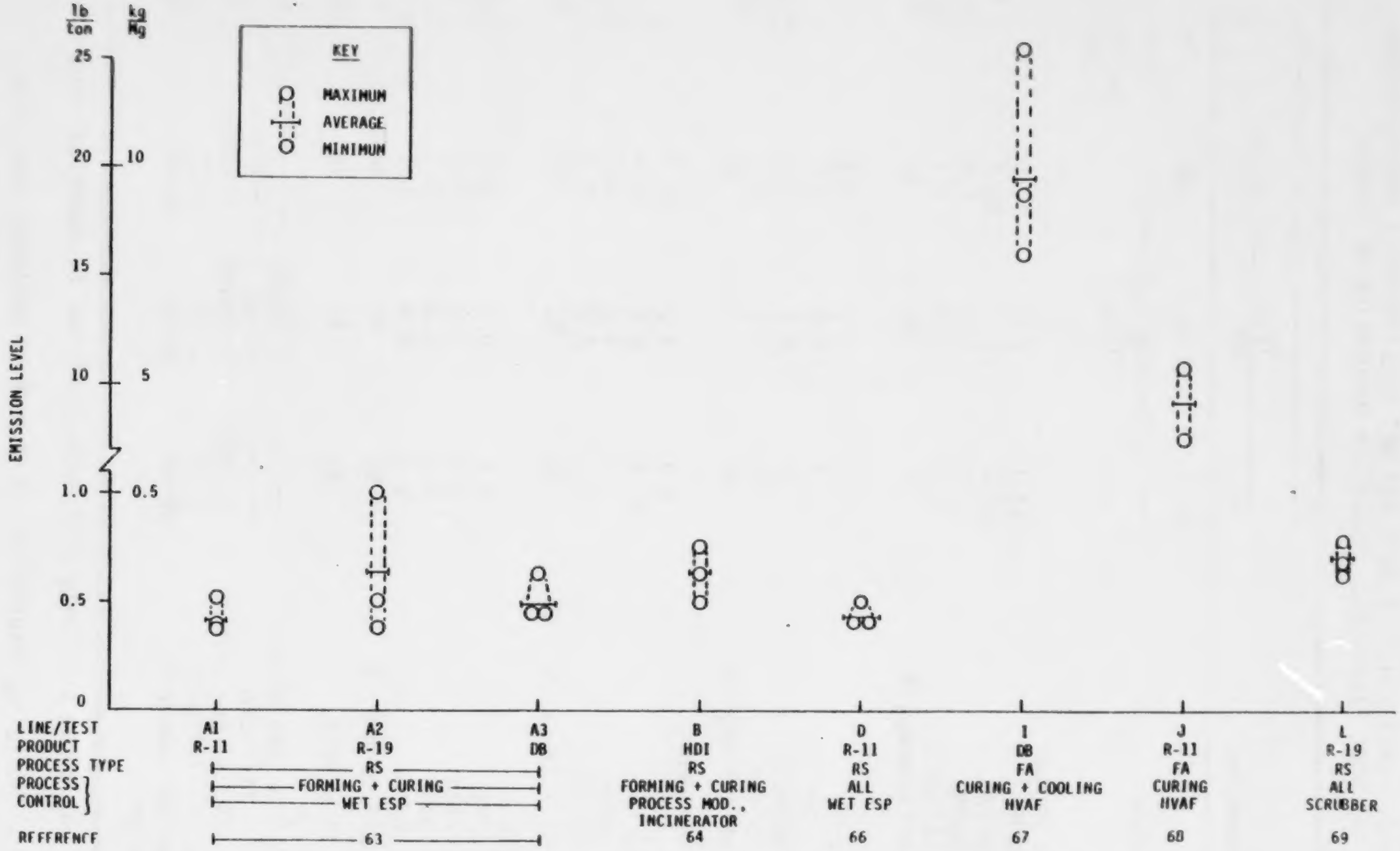


Figure 4-17. Total formaldehyde emissions for controlled wool fiberglass insulation manufacturing lines.

TABLE 4-6. EMISSION TEST DATA FOR WET ELECTROSTATIC PRECIPITATORS AT WOOL FIBERGLASS INSULATION MANUFACTURING PLANTS[a]

Parameter measured	Line			
	Test			
	A1	A2	A3	D
Product[b]	R-11	R-19	DB	R-11
Process tested	Forming and Curing			Forming, Curing, and Cooling
Particulate matter				
Inlet, kg/Mg	47.1	19.5	40.0	7.7
Inlet, lb/ton	94.2	39.0	80.0	15.4
Outlet, kg/Mg	3.3	3.9	4.8	1.6
Outlet, lb/ton	6.5	7.9	9.7	3.2
Control efficiency, %	93	80	88	78
Phenol				
Inlet, kg/Mg	1.7	0.9	3.8	0.5
Inlet, lb/ton	3.4	1.8	7.7	1.0
Outlet, kg/Mg	1.0	0.9	1.9	0.4
Outlet, lb/ton	1.9	1.8	3.7	0.8
Control efficiency, %	40	1	52	22
Phenolic compounds				
Inlet, kg/Mg	15.7	3.2	11.7	1.7
Inlet, lb/ton	31.4	6.4	23.4	3.4
Outlet, kg/Mg	1.1	1.2	4.1	0.6
Outlet, lb/ton	2.2	2.4	8.2	1.2
Control efficiency, %	93	62	65	65
Formaldehyde				
Inlet, kg/Mg	1.4	0.5	2.1	1.3
Inlet, lb/ton	2.8	1.0	4.2	2.6
Outlet, kg/Mg	0.2	0.3	0.3	0.3
Outlet, lb/ton	0.4	0.6	0.5	0.5
Control efficiency, %	86	42	88	76
Inlet gas flow rate, % of design	82	83	78	108
Design SCA,[c] m^2 per m^3/min	0.00055			0.00128
ft^2/acfm	0.168			0.390
Operating SCA, m^3 per m^3/min	0.00069	0.00066	0.00069	0.00121
(average) ft^2/acfm	0.21	0.20	0.21	0.368
Line production capacity, % of design	68-86	88-92	86-97	100

[a] Data may not agree precisely with Appendix C due to numerical rounding error.

[b] R-11 = R-11 building insulation. R-19 = R-19 building insulation. DB = ductboard.

[c] SCA=specific collection area.

The wet ESP on line D controls emissions from forming, curing, and cooling. It is preceded by water sprays and low pressure drop scrubbers on forming and water sprays on curing and cooling. The forming section includes air recirculation, a process modification that reduces the air flow to the control device relative to the total air flow circulating through the forming section. Continuous mist sprays on the inlet to the wet ESP keep the collection plates wet; there is also a water wash system, which is operated intermittently to wash the collection plates. The mist sprays and water wash system were operated normally during the tests.

Three emission tests were performed on the wet ESP on line A. Each test was on a different product, R-11 BI, R-19 BI, and DB. On line D, one test was performed on R-11 BI. The density and LOI for each of the products tested are given in Chapter 3, Table 3-8. During the tests, the average inlet gas temperatures to the wet ESP's were 33°C (91°F) for line A and 47°C (117°F) for line D.

The lower emission level was achieved on line D. The outlet particulate level was 1.6 kg/Mg (3.2 lb/ton) on line D and ranged from 3.3 to 4.8 kg/Mg (6.6 to 9.8 lb/ton) on line A. The higher ESP efficiency was on line A. The efficiency ranged from 80 to 93 percent on line A and was 78 percent on line D.

The wet ESP's on lines A and D also removed phenol, phenolic compounds, and formaldehyde. The controlled levels ranged from 0.4 to 1.9 kg/Mg (0.8 to 3.7 lb/ton) for phenol, from 0.6 to 4.1 kg/Mg (1.2 to 8.2 lb/ton) for phenolic compounds, and from 0.2 to 0.3 kg/Mg (0.4 to 0.6 lb/ton) for formaldehyde. Control efficiencies ranged from 1 to 52 percent for phenol, 62 to 93 percent for phenolic compounds, and from 42 to 88 percent for formaldehyde.

4.6.2 Wet scrubbers

High pressure drop venturi scrubbers were source tested at line L. Emission data and specific operating parameters during each test are shown in Table 4-7. Forming emissions are controlled by two scrubbers in parallel (designated as the "25" and "50" scrubbers). These scrubbers are preceded by five cyclone separators on the common inlet duct. Forming air recirculation is also used on this line. Curing and cooling

TABLE 4-7. EMISSION TEST DATA FOR VENTURI SCRUBBERS AT A WOOL FIBERGLASS INSULATION MANUFACTURING PLANT[a]

Parameter measured	Line L	
Product[b]	R-19	R-19
Process tested	Forming	Curing and cooling
Particulate matter		
Inlet, kg/Mg	3.5	0.9
Inlet, lb/ton	7.0	1.7
Outlet, kg/Mg	1.0	0.3
Outlet, lb/ton	2.0	0.5
Control efficiency, %	72	68
Phenol		
Inlet, kg/Mg	0.5	0.1
Inlet, lb/ton	1.1	0.2
Outlet, kg/Mg	0.4	0.1
Outlet, lb/ton	0.7	0.2
Control efficiency,%	31	13
Phenolic compounds		
Inlet, kg/Mg	1.3	0.2
Inlet, lb/ton	2.6	0.4
Outlet, kg/Mg	0.5	0.1
Outlet, lb/ton	1.0	0.2
Control efficiency, %	63	40
Formaldehyde		
Inlet, kg/Mg	0.7	0.1
Inlet, lb/ton	1.4	0.2
Outlet, kg/Mg	0.3	0.1
Outlet, lb/ton	0.6	0.1
Control efficiency, %	60	41
Inlet gas flow rate, % of design	--[c]	87
Pressure drop		
kPa	7.3-8.3	6.8-6.9
in. w.c.	29-33	27-28
Line production capacity, % of design	100	102

[a] Data may not agree precisely with Appendix C due to numerical rounding error.

[b] R-19 = R-19 building insulation.

[c] Not determined due to common scrubber inlet sampling location.

emissions are ducted together and controlled by a third venturi scrubber. Water sprays are located in the ductwork from the curing oven to the scrubber.

Simultaneous inlet and outlet tests were performed on the forming scrubbers and on the curing/cooling scrubber. For the forming scrubbers, sampling was conducted at the common inlet to both scrubbers and at each of the two outlets. Testing was performed during the production of R-19 BI. The density and LOI of the product are shown in Chapter 3, Table 3-8. During the tests, the pressure drop of the forming scrubbers ranged from 7.3 to 8.3 kilopascals (kPa) (29.4 to 33.3 inches of water column [in. w.c.]), and the pressure drop of the curing/cooling scrubber ranged from 6.8 to 6.9 kPa (27.3 to 27.6 in. w.c.).

The outlet particulate level for line L was 1.3 kg/Mg (2.5 lb/ton), and the overall scrubber efficiency was 71 percent. The outlet emission levels of phenol, phenolic compounds, and formaldehyde were 0.5 kg/Mg (0.9 lb/ton), 0.6 kg/Mg (1.2 lb/ton), and 0.3 kg/Mg (0.7 lb/ton), respectively. Overall scrubber efficiency was 28 percent for phenol, 60 percent for phenolic compounds, and 58 percent for formaldehyde.

4.6.3 HVAF's

Emission testing was conducted on HVAF's controlling emissions from one RS line, C, and two FA lines, I and J. The emissions data and specific operating parameters during each test are presented in Table 4-8.

The HVAF on line C controls emissions from curing and cooling. The HVAF is a vendor-supplied unit that contains a cooling chamber with water sprays to cool the inlet gases and a demister to capture liquid droplets that are entrained in the exhaust gas. The inlet water sprays and demister were operating during the tests on line C.

The HVAF on line I controls emissions from curing and cooling. On line J, the HVAF controls emissions from curing alone. The HVAF's on lines I and J are of company design and construction and use neither precooling sections nor demisters.

During the tests, R-11 BI was produced on lines C and J and DB was produced on line I. The average inlet gas temperatures to the HVAF's were 35°C (95°F) on line C, 67°C (153°F) on line I, and 68°C (154°F) on line J.

TABLE 4-8. EMISSION TEST DATA FOR HIGH VELOCITY AIR FILTERS AT WOOL FIBERGLASS INSULATION MANUFACTURING PLANTS[a]

	Line		
Parameter measured	C	I	J
Product[b]	R-11	DB	R-11
Process tested	-- Curing and Cooling --		Curing
Particulate matter			
Inlet, kg/Mg	3.0	3.0	2.2
Inlet, lb/ton	6.0	6.0	4.4
Outlet, kg/Mg	0.6	0.6	1.2
Outlet, lb/ton	1.1	1.1	2.5
Control efficiency, %	81	80[c]	41
Phenol			
Inlet, kg/Mg	0.2	0	0.1
Inlet, lb/ton	0.4	0.1	0.2
Outlet, kg/Mg	0.2	0	0.1
Outlet, lb/ton	0.3	0.1	0.2
Control efficiency, %	12	0[c]	0
Phenolic compounds			
Inlet, kg/Mg	0.4	0.4	0.2
Inlet, lb/ton	0.8	0.8	0.4
Outlet, kg/Mg	0.2	0.2	0.2
Outlet, lb/ton	0.4	0.5	0.4
Control efficiency, %	55	19[c]	0
Formaldehyde			
Inlet, kg/Mg	0.2	0.4	0.5
Inlet, lb/ton	0.3	0.8	1.0
Outlet, kg/Mg	0.1	0.4	0.5
Outlet, lb/ton	0.2	0.8	1.0
Control efficiency, %	54	0[c]	0
Inlet gas flow rate, % of design	62	56	69
HVAF pressure drop, kPa	5.2	2.7	2.5-7.5[d]
in. w.c.	21	11	10-30[d]
Filter advance rate, cm/h	15.2	71.1	35.6
in./h	6	28	14
Cooling spray operation	On	Off	Off
Line production capacity, % of design	92	99	100

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[a] Data may not agree precisely with Appendix C due to numerical rounding error.

[b] R-11 = R-11 building insulation. DB = ductboard.

[c] Based on nonsimultaneous inlet and outlet tests.

[d] Design pressure drop; actual not recorded due to broken manometer.

The outlet particulate emissions level achieved by the HVAF's were 0.2 kg/Mg (0.4 lb/ton) on line C, 0.6 kg/Mg (1.1 lb/ton) on line I, and 1.3 kg/Mg (2.6 lb/ton) on line J. The corresponding particulate removal efficiencies were 81 percent on line C, 80 percent on line I, and 41 percent on line J.

The HVAF on line C was more efficient in removing phenol, phenolic compounds, and formaldehyde than the HVAF's on lines I and J. The HVAF on line C achieved efficiencies of 17 percent, 57 percent, and 54 percent on phenol, phenolic compounds, and formaldehyde, respectively. On line I, the HVAF controlled 19 percent of the phenolic compounds but achieved no control on phenol and formaldehyde. The HVAF on line J achieved no control of these compounds.

4.6.4 Incinerators

Emission testing was conducted on an incinerator controlling emissions from curing on line B. Emission data and specific operating parameters during the test are shown in Table 4-9. Only outlet emissions could be measured; therefore, no control efficiencies could be determined.

During the test, HDI was produced on line B. The incinerator controlled particulate emissions to a level of 0.2 kg/Mg (0.4 lb/ton) and controlled phenol, phenolic compounds, and formaldehyde to zero.

4.6.5 Process Modifications

Emission tests were performed on line B where process modifications are a part of the control system. Emission data for line B are shown in the summary Tables 4-2 through 4-5. In addition to process modifications, low pressure drop scrubbers and cyclones are used to control forming emissions. The description of the process modifications is held confidential by the company.

During testing, HDI was produced on line B. The combined controlled emissions from forming and from the incinerator on curing were 2.0 kg/Mg (4.0 lb/ton) of particulate matter, 0.4 kg/Mg (0.7 lb/ton) of phenol, 0.5 kg/Mg (0.9 lb/ton) of phenolic compounds, and 0.3 kg/Mg (0.6 lb/ton) of formaldehyde.

4.6.6 Visible Emissions Data

Data obtained from the EPA testing program for visible emissions are summarized in Table 4-10. No visible emissions data were obtained

TABLE 4-9. EMISSION TEST DATA FOR INCINERATOR AT A WOOL FIBERGLASS INSULATION MANUFACTURING PLANT[a]

Parameter measured	Line B
Product[b]	HDI
Process tested	Curing
Particulate matter	
Outlet, kg/Mg	0.2
Outlet, lb/ton	0.4
Phenol	
Outlet, kg/Mg	0
Outlet, lb/ton	0
Phenolic compounds	
Outlet, kg/Mg	0
Outlet, lb/ton	0
Formaldehyde	
Outlet, kg/Mg	0
Outlet, lb/ton	0
Outlet gas flow, % of design	79
Outlet gas temperature, °C/°F	643/1188
Combustion temperature, % of design	98
Fuel consumption, % of design	93
Line production capacity, % of design	89

[a] Inlets not measured because of duct configuration.
[b] HDI = heavy density insulation.

TABLE 4-10. SUMMARY OF VISIBLE EMISSION DATA[63-69]

Line/ test	Process source	Product[a]	Control device	No. of 6-min. avg.	Range of 6-minute average opacities, percent	No. of 6-minute averages greater than--					
						5	10	15	20	25	30
A1	Rotary spin forming and curing	R-11	Wet ESP	40	6-12	40	4	0	0	0	0
A2	Rotary spin forming and curing	R-19	Wet ESP	41	8-10	41	0	0	0	0	0
A3	Rotary spin forming and curing	DB	Wet ESP	44	11-29	44	44	21	13	3	0
B	Rotary spin forming and curing	HDI	Process modifications, incinerator	51	5	0	0	0	0	0	0
I	Flame attenuation curing and cooling	DB	HVAF	25	0-1	0	0	0	0	0	0
J	Flame attenuation curing	R-11	HVAF	38	0-4	0	0	0	0	0	0
L	Rotary spin forming, curing, and cooling	R-19	Wet scrubbers	115	11-31	115	115	112	85	23	2

[a] R-11 = R-11 building insulation. R-19 = R-19 building insulation. DB = ductboard.
HDI = heavy density insulation.

for lines C and D because the exhaust gases from these lines are ducted to stacks shared with other operating processes. The maximum opacity (6-min. average) for forming and curing on RS line A was 12 percent for the test on R-11 BI, 10 percent for the test on R-19 BI, and 29 percent for the test on DB. For RS line B, the maximum opacity for forming and curing for the test on HDI was 5 percent. The maximum opacities measured for curing and cooling on FA line I during the production of DB and for curing on FA line J during the production of R-11 BI were 1 and 4 percent, respectively. The maximum opacity observed on RS line L for combined forming, curing, and cooling emissions was 31 percent.

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5. MODIFICATION AND RECONSTRUCTION

Standards of performance apply to facilities for which construction, modification, or reconstruction commenced (as defined under 40 CFR 60.2) after the date of proposal of the standards. Such facilities are termed "affected facilities." Standards of performance are not applicable to "existing facilities" (i.e., facilities for which construction, modification, or reconstruction commenced on or before the date of proposal of the standards). An existing facility may become an affected facility and therefore be subject to standards if the facility undergoes modification or reconstruction.

Modification and reconstruction are defined under 40 CFR 60.14 and 60.15, respectively. These general provisions are summarized in Section 5.1. Section 5.2 discusses the applicability of these provisions to fiberglass manufacturing plants.

5.1 PROVISIONS FOR MODIFICATION AND RECONSTRUCTION

5.1.1 Modification

With certain exceptions, any physical or operational change to an existing facility that would increase the emission rate to the atmosphere from that facility of any pollutant covered by the standard would be considered a modification within the meaning of Section 111 of the Clean Air Act. The key to determining if a change is considered a modification is whether the total emission rate to the atmosphere from the facility increased as a result of the change. Under the current regulations, an emission increase from one facility may not be offset with a similar emission decrease at another facility to avoid becoming subject to new source performance standards (NSPS). If an existing facility is determined to be modified, all of the emission sources of that facility are subject to the standards of performance applicable to the pollutant for which the emission rate increased. A modification to one existing facility at a plant will not cause other existing facilities at the same plant to become subject to the standards.

Under the regulations, certain physical or operational changes are not considered to be modifications even though emissions may increase as a result of the change (see 40 CFR 60.14(e)). For the most part, these exceptions are allowed because they account for fluctuations in emissions that do not cause a facility to become a significant new source of air pollution. The exceptions as allowed under 40 CFR 60.14(e) are as follows:

1. Routine maintenance, repair, and replacement (e.g., lubrication of mechanical equipment; replacement of pumps, motors, and piping; cleaning of pipes and ductwork);
2. An increase in the production rate without a capital expenditure, (as defined in 40 CFR 60.2);
3. An increase in the hours of operation;
4. Use of an alternative fuel or raw material if, prior to proposal of the standard, the existing facility was designed to accommodate that alternate fuel or raw material;
5. The addition or use of any system or device whose primary function is to reduce air pollutants, except when an emission control system is replaced by a system determined by the EPA to be less environmentally beneficial; and
6. Relocation or change in ownership of the existing facility.

An owner or operator of an existing facility who is planning a physical or operational change that may increase the emission rate of a pollutant to which a standard applies shall notify the appropriate EPA regional office 60 days prior to the change, as specified in 40 CFR 60.7(a)(4).

5.1.2 Reconstruction

An existing facility may become subject to new source performance standards if it is reconstructed. Reconstruction is defined as the replacement of the components of an existing facility to the extent that (1) the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost required to construct a comparable new facility and (2) it is technically and economically feasible for the facility to meet the applicable standards. Because the EPA considers reconstructed facilities to constitute new construction rather than modification, reconstruction determinations are made irrespective of changes in emission rates. If the fixed capital cost of routine maintenance, repair, or replacement met the definition, the facility would be considered reconstructed.

The purpose of the reconstruction provisions is to discourage the perpetuation of an existing facility for the sole purpose of circumventing a standard that is applicable to new facilities. Without such a provision, all but vestigial components (such as frames, housing, and support structures) of the existing facility could be replaced without causing the facility to be considered a "new" facility subject to NSPS. If the facility is determined to be reconstructed, it must comply with all of the provisions of the standards of performance applicable to that facility.

If an owner or operator of an existing facility is planning to replace components and the fixed capital cost of the new components exceeds 50 percent of the fixed capital cost of a comparable new facility, the owner or operator must notify the appropriate EPA regional office 60 days before the construction of the replacement commences, as required under 40 CFR 60.15(d).

5.2 APPLICATION TO WOOL FIBERGLASS MANUFACTURING FACILITIES

5.2.1 Modification

Potential modifications of fiberglass manufacturing equipment and processes that could increase the emission rate might include:

1. Installation of additional spinners in the forming section to increase glass pull rate beyond design capacity or increase of line speed capability beyond design speed to increase throughput;
2. Increasing the width of a production line to manufacture a wider fiberglass mat; and
3. Rebuilding a curing oven to obtain greater heat input or higher curing air flow.

5.2.2 Reconstruction

Reconstruction, as defined under 40 CFR 60.15, might occur if the components of a forming section, curing oven, or cooling section are replaced, and if the fixed capital cost of the replacement components exceeded 50 percent of the fixed capital cost of a new affected facility. Conversion of an existing line from flame attenuation to rotary spin forming technology would be considered reconstruction. Reconstruction in the wool fiberglass industry is expected to occur only in isolated cases.

6. MODEL PLANTS AND REGULATORY ALTERNATIVES

6.1 PURPOSE

Model lines, model plants, and regulatory alternatives for wool fiberglass insulation manufacturing are defined in this chapter. Model lines characterize the range of lines that are expected to be constructed in the future. Model plants consist of representative combinations of model lines and of model line additions to existing plants. Regulatory alternatives are defined for the model lines. These model lines, model plants, and regulatory alternatives are used in subsequent chapters as the basis for analysis of the environmental, energy, and economic impacts associated with control of emissions from wool fiberglass insulation manufacturing facilities.

6.2 MODEL LINES

Schematics of rotary spin (RS) and flame attenuation (FA) wool fiberglass manufacturing lines are presented in Figures 6-1 and 6-2, respectively. (See Chapter 3 for descriptions of RS and FA lines and Chapter 4 for descriptions of control devices and control configurations.) Four RS model line sizes (specialty, small, medium, and large) and one FA model line (small) have been selected to characterize the range of wool fiberglass insulation manufacturing lines expected to be constructed, modified, or reconstructed in the future. The RS and FA line sizes and technical parameters are presented in Tables 6-1 and 6-2, respectively. The designations for line size are based on annual production capacity in megagrams per year (Mg/yr) (tons/yr). Development of model line parameters utilized data from EPA source tests, from the industry, and from plant visits.

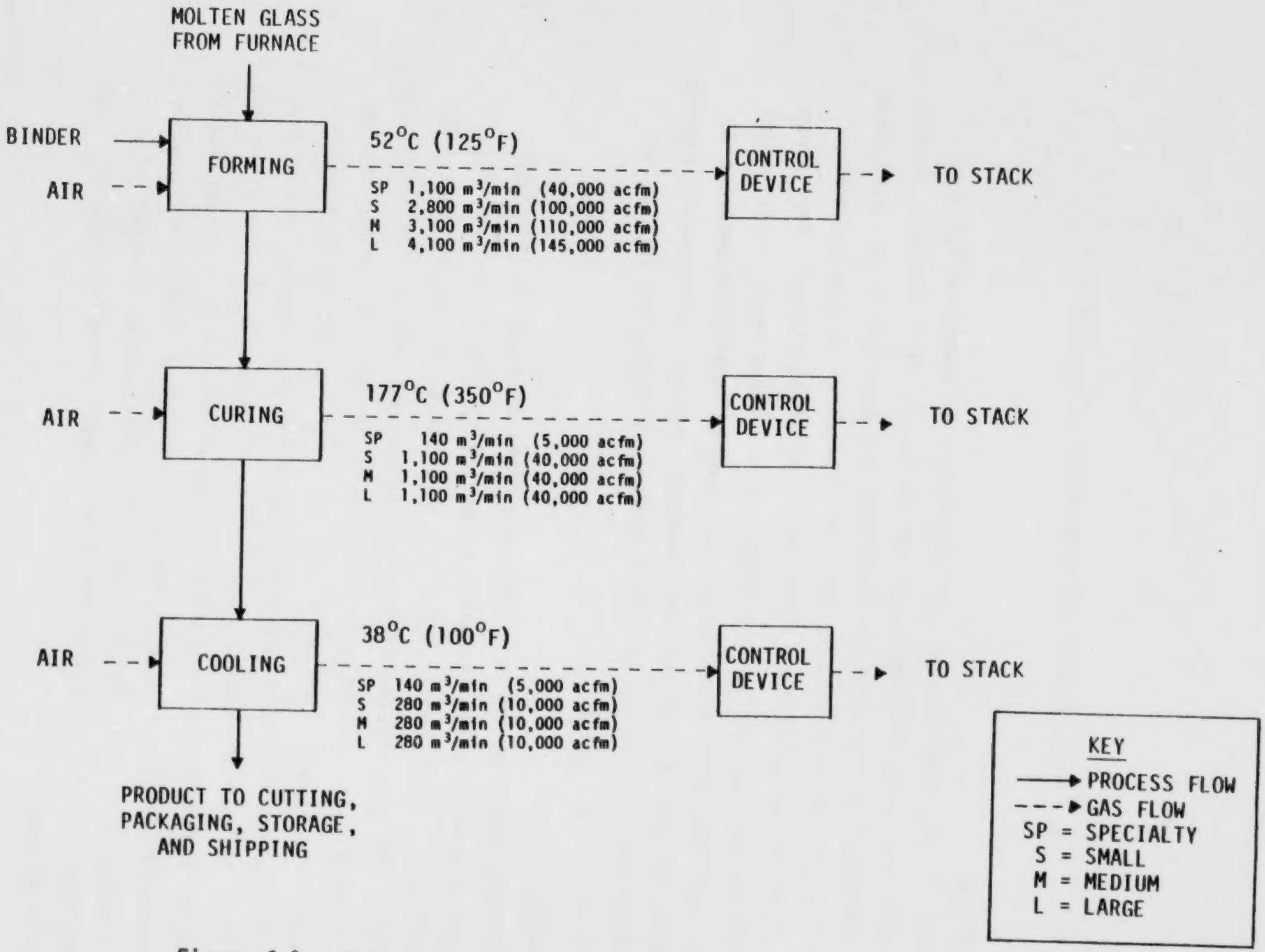
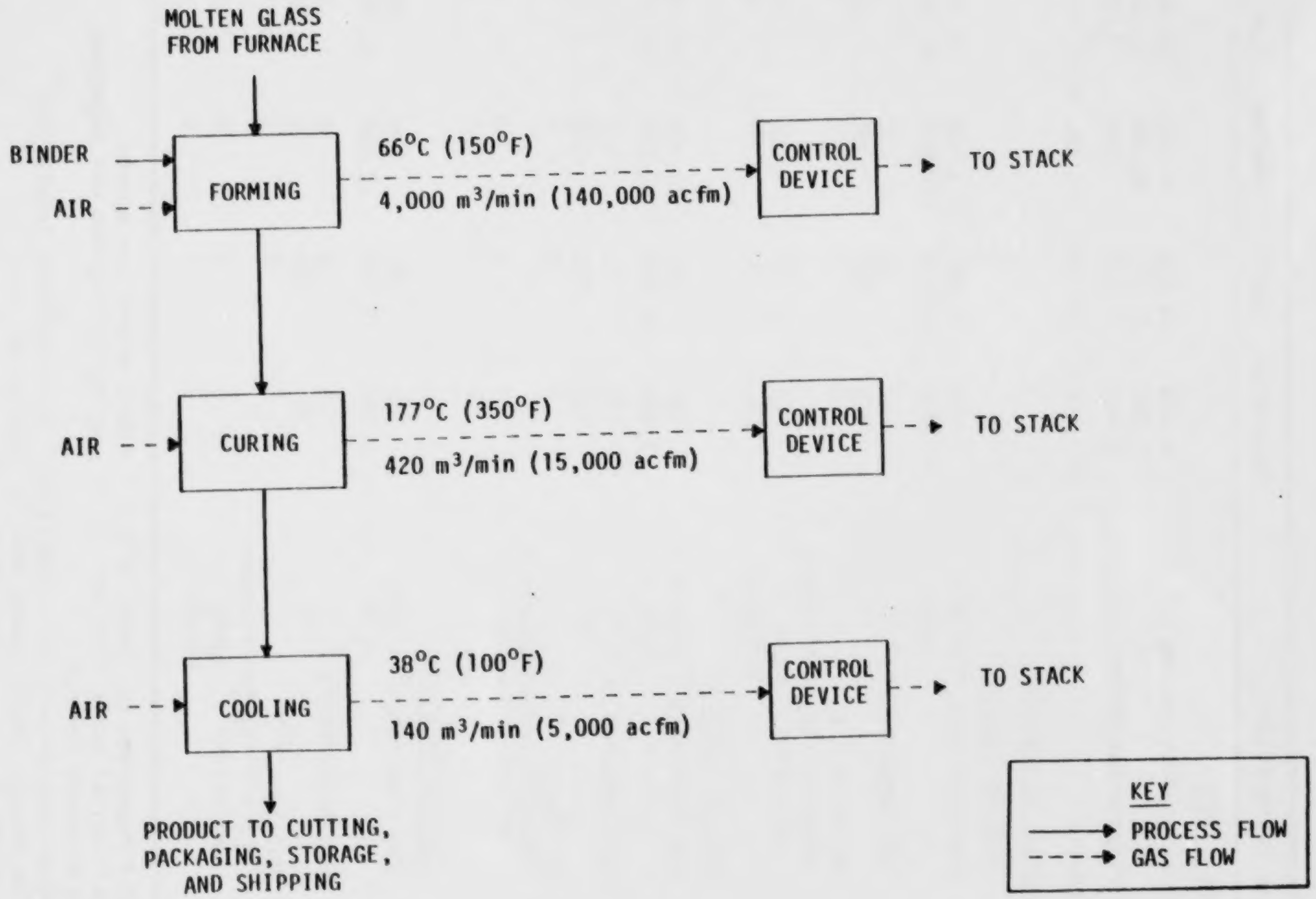

MOLTEN GLASS FROM FURNACE
BINDER
AIR
FORMING
52°C (125°F)
SP 1,100 m³/min (40,000 acfm)
S 2,800 m³/min (100,000 acfm)
M 3,100 m³/min (110,000 acfm)
L 4,100 m³/min (145,000 acfm)
CONTROL DEVICE
TO STACK
AIR
CURING
177°C (350°F)
SP 140 m³/min (5,000 acfm)
S 1,100 m³/min (40,000 acfm)
M 1,100 m³/min (40,000 acfm)
L 1,100 m³/min (40,000 acfm)
CONTROL DEVICE
TO STACK
AIR
COOLING
38°C (100°F)
SP 140 m³/min (5,000 acfm)
S 280 m³/min (10,000 acfm)
M 280 m³/min (10,000 acfm)
L 280 m³/min (10,000 acfm)
CONTROL DEVICE
TO STACK
PRODUCT TO CUTTING, PACKAGING, STORAGE, AND SHIPPING
KEY
PROCESS FLOW
GAS FLOW
SP = SPECIALTY
S = SMALL
M = MEDIUM
L = LARGE

Figure 6-1. Schematic of a rotary spin line showing gas flows.



MOLTEN GLASS FROM FURNACE
BINDER
AIR
FORMING
66°C (150°F)
4,000 m³/min (140,000 acfm)
CONTROL DEVICE
TO STACK
AIR
CURING
177°C (350°F)
420 m³/min (15,000 acfm)
CONTROL DEVICE
TO STACK
AIR
COOLING
38°C (100°F)
140 m³/min (5,000 acfm)
CONTROL DEVICE
TO STACK
PRODUCT TO CUTTING, PACKAGING, STORAGE, AND SHIPPING
KEY
PROCESS FLOW
GAS FLOW

Figure 6-2. Schematic of a flame attenuation line showing gas flows.

TABLE 6-1. MODEL LINE PARAMETERS--ROTARY SPIN

Line designation:	Specialty	Small	Medium	Large
1. Line information				
Annual production, Mg/yr[a]	4,500	18,000	34,000	50,000
tons/yr	5,000	20,000	38,000	55,000
Hours/year operation	8,000	8,000	8,000	8,000
Products	(PI, SP)[b]	— (BI, PI, DB, HDI)[b] —		
2. Process information				
A. Forming Section				
Gas flow rate,[c] m^3/min	1,100	2,800	3,100	4,100
acfm	40,000	100,000	110,000	145,000
Gas temperature,[c] °C	52	52	52	52
°F	125	125	125	125
Moisture,[c] %	6	6	6	6
Uncontrolled particulate emissions,[d] kg/Mg	26	26	26	26
lb/ton	52	52	52	52
B. Curing Section				
Gas flow rate,[c] m^3/min	140	1,100	1,100	1,100
acfm	5,000	40,000	40,000	40,000
Gas temperature,[c] °C	177	177	177	177
°F	350	350	350	350
Moisture,[c] %	6	6	6	6
Uncontrolled particulate emissions,[d] kg/Mg	3	3	3	3
lb/ton	5	5	5	5
C. Cooling Section				
Gas flow rate,[c] m^3/min	140	280	280	280
acfm	5,000	10,000	10,000	10,000
Gas temperature,[c] °C	38	38	38	38
°F	100	100	100	100
Moisture,[c] %	2	2	2	2
Uncontrolled particulate emissions[d,e] kg/Mg	0	0	0	0
lb/ton	0	0	0	0

[a] Mg/yr = megagrams per year; m^3/min = cubic meters per minute; acfm = actual cubic feet per minute; kg/Mg = kilograms per megagram; lb/ton = pounds per ton.

[b] PI = Pipe insulation. SP = Specialty. BI = Building insulation. DB = Ductboard. HDI = Heavy density insulation.

[c] At the exit of each section of the process.

[d] Average total catch for all line sizes from EPA test data.

[e] Data less than 0.25 kg/Mg (0.5 lb/ton) round to zero.

TABLE 6-2. MODEL LINE PARAMETERS--FLAME ATTENUATION

Line designation:	Small
1. Line information	
Annual production, Mg/yr[a]	4,500
tons/yr	5,000
Hours/year operation	8,000
Products	(BI, PI, DB, SP, HDI)[b]
2. Process information	
A. Forming Section	
Gas flow rate,[c] m^3/min	4,000
acfm	140,000
Gas temperature,[c] °C	66
°F	150
Moisture,[c] %	6
Uncontrolled particulate emissions,[d] kg/Mg	44
lb/ton	89
B. Curing Section	
Gas flow rate,[c] m^3/min	420
acfm	15,000
Gas temperature,[c] °C	177
°F	350
Moisture,[c] %	6
Uncontrolled particulate emissions,[d] kg/Mg	3
lb/ton	5
C. Cooling Section	
Gas flow rate,[c] m^3/min	140
acfm	5,000
Gas temperature,[c] °C	38
°F	100
Moisture,[c] %	2
Uncontrolled particulate emissions,[d,e] kg/Mg	1
lb/ton	1

---

[a] Mg/yr = megagrams per year. m^3/min = cubic meters per minute. acfm = actual cubic feet per minute. kg/Mg = kilograms per megagram. lb/ton = pounds per ton.

[b] BI = Building insulation. PI = Pipe insulation. DB = Ductboard. SP = Specialty. HDI = Heavy density insulation.

[c] At the exit of each section of the process.

[d] Based on highest total catch from EPA test data on FA lines.

[e] kg/Mg equal lb/ton due to numerical rounding.

The raw materials for wool fiberglass insulation manufacturing are molten glass and binder, which typically consists of an aqueous solution of phenol-formaldehyde resin and other minor constitutents.

A number of wool fiberglass insulation products are made on RS and FA lines. The principal products are building insulation (BI) (includes residential and nonresidential), heavy density insulation (HDI), ductboard (DB), and pipe insulation (PI). With the exception of PI, these products could all be made by any of the model lines described in Tables 6-1 and 6-2. Pipe insulation is manufactured (with one exception in the industry) on lines dedicated to this product and at low production rates relative to other products. A separate model line, termed "specialty," has been developed to characterize the production of PI. This model line will also represent lines that produce other specialty products (such as automobile or appliance insulation). Larger pipe or specialty lines that might be constructed would be represented by one of the other three RS model lines.

Gas flow rates vary among companies and products. Gas flow rates for high density products (e.g., DB and HDI) are lower than flow rates for low density products (e.g., BI). The greatest variation in gas flow rates is from company to company. The model line gas flow rates presented in Tables 6-1 and 6-2 were obtained from industry data and EPA source test reports for existing lines.

Within each RS line size designation, forming gas flow rates vary widely. However, as line production capacity increases, a nearly linear increase in forming gas flow rate is typical for all lines. The forming gas flows selected for the four model line sizes are considered to be typical. Curing and cooling gas flow rates show no relationship with line production capacity except for the specialty line. Therefore, typical curing and cooling gas flows of 1,100 and 280 cubic meters per minute (m^3/min) (40,000 and 10,000 actual cubic feet per minute [acfm]), respectively, were selected for all three of the largest model line sizes. These figures are based on the average gas flows for existing lines ranging in size from small to large. A gas flow of 140 m^3/min (5,000 acfm) was selected for the specialty line curing and cooling flows. There are no known corrosive properties of the gas stream that require special materials of construction.

Estimates of uncontrolled particulate emissions from EPA test data are given in Tables 6-1 and 6-2 for forming, curing, and cooling. These are expressed as kilograms per megagram (kg/Mg) (pounds per ton [lb/ton]) of glass pulled.

6.3 MODEL PLANTS

Two types of RS model plants are defined for wool fiberglass manufacturing: (1) complete new plants and (2) single line additions to existing plants. Complete model plants were developed from available information on production capacity and the number of lines at existing facilities. The range of production capacity for each size of model plant is presented in Table 6-3 as well as possible line combinations that make up each model plant. Combinations of line sizes were selected to include the four model line sizes and to cover a wide range of model plant sizes, environmental impacts, and economic impacts.

The low air flow rates associated with specialty RS lines may result in control configurations in which emissions from a specialty line are ducted with emissions from a larger line to a common control device. For the medium-sized model plant (Table 6-3), for example, emissions from the specialty line could be ducted to a control device on one of the two large lines.

No new FA plants are expected to be built by the industry. Table 6-4 presents model plants that represent the addition of single RS or FA lines (as defined in Tables 6-1 and 6-2) to existing wool fiberglass manufacturing plants.

6.4 REGULATORY ALTERNATIVES

Regulatory alternatives with the associated control device configurations are presented in Tables 6-5 and 6-6 for RS and FA processes, respectively. Emission levels that are used to analyze the relative impacts of regulatory alternatives are given in Tables 6-7 and 6-8 for RS and FA processes, respectively. The emission levels were developed from test data and measured control device efficiencies.[1] In all calculations, it was assumed that each control device would achieve the same control efficiency on each combination of emission sources used in the regulatory alternatives. The test data show no correlation between controlled emissions levels and

TABLE 6-3. MODEL PLANTS (COMPLETE PLANTS)

Model plant No.	Plant type[a]	Plant size[b]	Range of annual production capacity Mg/yr[c]	Range of annual production capacity tons/yr	Possible model line combinations[d]
1	RS	S	18,000-57,000	20,000-63,000	*1 small 1 large 1 small, 1 medium, and 1 specialty
2	RS	M	68,000-104,000	75,000-115,000	*2 large and 1 specialty 1 small and 2 medium 1 small and 1 large
3	RS	L	134,000-177,000	148,0000-195,000	*1 small, 1 medium, and 2 large 1 medium and 2 large 5 medium and 1 specialty

[a] RS = rotary spin.
[b] S = small.
M = medium.
L = large.
[c] Mg/yr = megagrams per year.
[d] Asterisks indicate combinations recommended for economic impact analysis.

TABLE 6-4. MODEL PLANTS (LINE ADDITION)

Model plant No.	Line type[a]	Line designation	Increased production capacity Mg/yr[b]	Increased production capacity tons/yr
4	RS	Small	18,000	20,000
5	RS	Medium	34,000	38,000
6	RS	Large	50,000	55,000
7	FA	Small	4,500	5,000

[a] RS = rotary spin.
FA = flame attenuation.

[b] Mg/yr = megagrams per year.

TABLE 6-5. ROTARY SPIN REGULATORY ALTERNATIVES AND CONTROL DEVICE CONFIGURATIONS

Regulatory alternative	Control device configuration(s) on--		
	Forming	Curing	Cooling
I (Baseline)	5-in. scrubber	600°F incinerator	Uncontrolled
II	Wet ESP 35-in. scrubber	600°F incinerator 600°F incinerator	Uncontrolled
III	Wet ESP 35-in. scrubber	Wet ESP 35-in. scrubber	Uncontrolled
IV	Wet ESP 35-in. scrubber	Wet ESP 35-in. scrubber	Wet ESP 35-in. scrubber

TABLE 6-6. FLAME ATTENUATION REGULATORY ALTERNATIVES AND CONTROL DEVICE CONFIGURATIONS

Regulatory alternative	Process		
	Forming	Curing	Cooling
I (Baseline)	Uncontrolled	Uncontrolled	Uncontrolled
II	Uncontrolled	HVAF	Uncontrolled
III	Uncontrolled	HVAF	HVAF
IV	HVAF	Uncontrolled	Uncontrolled

TABLE 6-7. ROTARY SPIN EMISSION LEVELS

Regulatory alternative	Specialty		Small		Medium		Large	
	kg/Mg[a]	lb/ton[a]	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
I (Baseline)	16	32	16	32	16	32	16	32
II	5	11	5	11	5	11	5	11
III	3	6	3	6	3	6	3	6
IV[b]	3	6	3	6	3	6	3	6

[a] kg/Mg = kilograms per megagram.
lb/ton = pounds per ton.

[b] Emission levels under Regulatory Alternative IV appear the same as those under Regulatory Alternative III due to numerical rounding.

TABLE 6-8. FLAME ATTENUATION EMISSION LEVELS

Regulatory alternative	Small	
	kg/Mg[a]	lb/ton[a]
I (Baseline)	47	95
II	45	90
III[b]	45	90
IV	12	24

[a] kg/Mg = kilograms per megagram.
lb/ton = pounds per ton.

[b] Emission levels under Regulatory Alternative III appear the same as those under Regulatory Alternative II due to numerical rounding.

the densities of the products. Therefore, it is assumed that the control levels shown for the various regulatory alternatives could be achieved for any product by a properly designed and operated control device.

The emission levels for the regulatory alternatives are intended to cover a range from baseline to successively more stringent control so that a range of potential impacts can be considered in selecting regulatory alternatives on which to base a new source performance standard (NSPS). The NSPS will be based on the test data and results of the impact analysis. Therefore, the numerical standard may not be exactly equal to any particular emissions level associated with the regulatory alternatives.

Regulatory Alternative I for both RS and FA is the baseline, the level of control that would be expected in the absence of a national standard. The remaining alternatives represent additional control of emissions from the wool fiberglass manufacturing process.

For RS lines, Regulatory Alternatives I, II, and III are based on control of forming and curing emissions. Under Regulatory Alternative IV, cooling emissions are also controlled. The regulatory alternatives are based on various combinations of control devices, which are listed in Table 6-5. Other control devices are possible but have not been considered as bases for regulatory alternatives. High velocity air filter (HVAF's), while used in the industry to control curing and cooling emissions, have not been demonstrated for control of forming emissions. Although emissions data were gathered from the only forming sections having dedicated control devices, these sections use recycled process air which is not typical industry practice. Thus, data are not available upon which to base regulatory alternatives employing more than one control device per alternative. (Regulatory Alternative II, while impractical to implement for the above reasons, is defined so that environmental and economic analyses can be performed on this level of control.) Similarly, process modifications are not considered as a technical basis for regulatory alternatives because they are not available for industry-wide use. Therefore, only wet ESP's and high pressure drop wet scrubbers are considered as bases for the more stringent levels of control under the regulatory alternatives. Control device system parameters for the model lines are presented in Table 6-9. These parameters are used in the evaluation of control device costs in Chapter 8.

For FA lines, Regulatory Alternative I (baseline) is based on uncontrolled forming, curing, and cooling. Regulatory Alternative II is based on control of curing with an HVAF. Curing and cooling both are controlled by HVAF's under Regulatory Alternative III, and forming alone is controlled by HVAF's under Regulatory Alternative IV. (Regulatory Alternative IV, while impractical to implement because HVAF's have not been demonstrated on forming emissions, is defined so that environmental and economic analyses can be performed on this level of control.) The HVAF parameters for FA lines are the same as those listed in Table 6-9 for RS lines.

6.5 REFERENCES FOR CHAPTER 6

1. Memo from W. Maxwell and J. Shular, MRI, to J. A. Telander, EPA/ISB/SDS. Alternative Control Technologies for Regulatory Alternatives (Amended). August 5, 1982.

TABLE 6-9. CONTROL DEVICE SYSTEM PARAMETERS FOR ROTARY SPIN LINES

Parameter[a]	Specification
Venturi Scrubber	
Water spray rate, ℓ/min per m^3/min (gpm/1,000 acfm)	2.0 (15)
Δp, Pa (in. w.c.)	
Regulatory Alternative I	1,245 (5)
Regulatory Alternatives II, III, IV	8,710 (35)
Wet ESP	
Water spray rate, ℓ/min per m^3/min (gpm/1,000 acfm)	1.3 (10)
Δp, Pa (in. w.c.)	250 (1)
Design efficiency, percent	90
Precipitation rate parameter, m/min (ft/min)	2.37 (7.78)
Specific collection area, m^2 per m^3/min (ft^2/1,000 acfm)	0.98 (300)
Incinerator	
Residence time, s	0.5
Operating temperature, °C (°F)	315 (600)
HVAF	
Water spray rate, ℓ/min per m^3/min (gpm/1,000 acfm)	2.0 (15)
Δp, Pa (in. w.c.)	6,970 (28)

[a] ℓ/min per m^3/min = liters per minute per cubic meter per minute.
gpm/1,000 acfm = gallons per minute per 1,000 actual cubic feet per minute.
Pa = pascals.
in. w.c. = inches water column.
ft/min = feet per minute.

7. ENVIRONMENTAL AND ENERGY IMPACTS

An analysis of the environmental and energy impacts of the regulatory alternatives for the wool fiberglass model lines and plants is presented in this chapter. The incremental increase or decrease in air pollution, water pollution, solid waste generation, and energy consumption for the regulatory alternatives as compared to baseline are discussed. Tables 7-1 and 7-2 present the control device configurations used in the impact analyses of the regulatory alternatives. The baseline control level represents no change from existing regulations. The regulatory alternatives are presented in Chapter 6.

7.1 AIR POLLUTION IMPACTS

This section presents an analysis of the air pollution impacts associated with application of each regulatory alternative on each model line and model plant.

7.1.1 Primary Air Impacts

7.1.1.1 Model Line (Plant) Emissions and Emission Reductions. Uncontrolled emission levels and emission levels associated with each regulatory alternative are presented in Tables 7-3 and 7-4. The emission levels were developed from EPA test data on uncontrolled emissions. Based on these levels, annual emissions of particulate matter are given in Tables 7-5 and 7-6 for rotary spin (RS) model lines and plants and in Table 7-7 for the flame attenuation (FA) model line. Tables 7-5 through 7-7 also show the emission reduction below baseline for the control alternatives for each model line and plant. The annual emissions were calculated using the production figures for the model lines and plants given in Table 7-8.

As shown in Tables 7-5 and 7-6, annual emissions for Regulatory Alternatives II through IV range from 53 to 264 Mg/yr (58 to 292 tons/yr)

TABLE 7-1. REGULATORY ALTERNATIVES AND CONTROL DEVICE CONFIGURATIONS FOR IMPACT ANALYSIS OF ROTARY SPIN LINES

Reg. Alt.	Control device configurations Forming	 Curing	 Cooling
I[a]	Wet scrubber 1.25 kPa (5 in.)	Incinerator 316°C (600°F)	Uncontrolled
II	Wet ESP[b] Wet scrubber 8.75 kPa (35 in.)	↓	↓
III	Wet ESP Wet scrubber 8.75 kPa (35 in.)	Wet ESP Wet scrubber 8.75 kPa (35 in.)	↓
IV	Wet ESP Wet scrubber 8.75 kPa (35 in.)	Wet ESP Wet scrubber 8.75 kPa (35 in.)	Wet ESP Wet scrubber 8.75 kPa (35 in.)

[a] Baseline.
[b] ESP = electrostatic precipitator.

TABLE 7-2. REGULATORY ALTERNATIVES AND CONTROL DEVICE CONFIGURATIONS FOR IMPACT ANALYSIS OF FLAME ATTENUATION LINES

Regulatory Alternative	Process		
	Forming	Curing	Cooling
I (Baseline)	Uncontrolled	Uncontrolled	Uncontrolled
II	Uncontrolled	HVAF	Uncontrolled
III	Uncontrolled	HVAF	HVAF
IV	HVAF[a]	Uncontrolled	Uncontrolled

[a] HVAF = high velocity air filter.

TABLE 7-3. SUMMARY OF PARTICULATE EMISSION LEVELS FOR ROTARY SPIN PROCESS[a] [1]

Regulatory Alternative	Emission level[b] kg/Mg of glass pulled	Emission level[b] lb/ton of glass pulled
Uncontrolled	29	58
I	16	32
II	5	11
III	3	6
IV	3	6

[a] Total line (forming, curing, and cooling).

[b] Emission levels are the same for some regulatory alternatives due to numerical rounding. Metric and English units may not convert exactly due to independent rounding.

TABLE 7-4. SUMMARY OF PARTICULATE EMISSION LEVELS FOR FLAME ATTENUATION PROCESS[a] [1]

Regulatory Alternative	Emission level[b] kg/Mg of glass pulled	lb/ton of glass pulled
I[c]	47	95
II	45	90
III	45	90
IV	12	24

[a] Total line (forming, curing, and cooling).

[b] Emission levels are the same for some regulatory alternatives due to numerical rounding. Metric and English units may not convert exactly due to independent rounding.

[c] Baseline = uncontrolled.

TABLE 7-5. ANNUAL PARTICULATE EMISSIONS FROM ROTARY SPIN MODEL LINES[1]

Line designation	Regulatory Alternative			
	I[a]	II	III	IV
Small				
Total				
Mg/yr[b]	287	96	55	53
tons/yr	316	106	61	58
Emission reduction below baseline				
Mg/yr	--	191	232	234
tons/yr	--	210	255	258
Medium				
Total				
Mg/yr	545	183	105	100
tons/yr	600	201	116	110
Emission reduction below baseline				
Mg/yr	--	362	440	445
tons/yr	--	399	484	490
Large				
Total				
Mg/yr	788	264	152	145
tons/yr	869	292	168	160
Emission reduction below baseline				
Mg/yr	--	524	636	643
tons/yr	--	577	701	709

[a] Baseline.

[b] Metric and English units may not convert exactly due to independent rounding.

TABLE 7-6. ANNUAL PARTICULATE EMISSIONS FROM ROTARY SPIN MODEL PLANTS[1]

Plant designation	Regulatory Alternative			
	I[a]	II	III	IV
1				
Total				
Mg/yr[b]	287	96	55	53
tons/yr	316	106	61	58
Emission reduction below baseline				
Mg/yr	--	191	232	234
tons/yr	--	210	255	258
2				
Total				
Mg/yr	1,648	552	318	303
tons/yr	1,817	611	351	333
Emission reduction below baseline				
Mg/yr	--	1,096	1,330	1,345
tons/yr	--	1,206	1,466	1,484
3				
Total				
Mg/yr	2,408	807	464	443
tons/yr	2,654	891	513	487
Emission reduction below baseline				
Mg/yr	--	1,601	1,944	1,965
tons/yr	--	1,763	2,141	2,167

[a] Baseline.

[b] Metric and English units may not convert exactly due to independent rounding.

TABLE 7-7. ANNUAL PARTICULATE EMISSIONS FROM FLAME ATTENUATION MODEL LINE[1]

Line designation	Regulatory Alternative			
	I[a]	II	III	IV
Small				
Total				
Mg/yr[b]	215	205	204	54
tons/yr	237	226	225	59
Emission reduction below baseline				
Mg/yr	--	10	11	161
tons/yr	--	11	12	178

[a] Baseline.

[b] Metric and English units may not convert exactly due to independent rounding.

TABLE 7-8. ANNUAL PRODUCTION FOR MODEL LINES AND PLANTS

Production:	Mg/yr	tons/yr
Rotary spin lines		
Small	18,000	20,000
Medium	34,000	38,000
Large	50,000	55,000
Rotary spin plants		
No. 1: 1 small line	18,000	20,000
No. 2: 2 large and 1 specialty line	104,500	115,000
No. 3: 1 small, 1 medium, and 2 large lines	152,000	168,000
Flame attenuation line		
Small	4,500	5,000

for the RS model lines and 53 to 807 Mg/yr (58 to 891 tons/yr) for the RS model plants. Baseline emissions are 287 to 788 Mg/yr (316 to 869 tons/yr) for the model lines and 287 to 2,408 Mg/yr (316 to 2,654 tons/yr) for the model plants. The national impact of Regulatory Alternatives II through IV on particulate emission reduction below baseline will range from 7,100 to 11,600 Mg/yr (7,800 to 12,800 tons/yr) in the fifth year after implementation of the standard. The fifth-year national impacts presented in this chapter are based on industry growth projections (projected numbers of new lines and plants) discussed in Chapter 9.

Annual emissions from the FA model line for Regulatory Alternatives II through IV range from 54 to 205 Mg/yr (59 to 226 tons/yr). The baseline emission level for the FA model line is approximately 215 Mg/yr (237 tons/yr). No fifth-year impacts of the FA regulatory alternatives are presented because no growth is projected for this segment of the industry.

In addition to the control of particulate matter, the control devices used to achieve the regulatory alternatives also reduce phenol and formaldehyde levels in the effluent gas stream. Emissions of these compounds are caused by vaporization and aerosolization of binder in the forming, curing, and cooling sections of the fiberglass manufacturing process. These compounds are removed from the gas stream by absorption into the water used in the control device or as cooling sprays and by adsorption onto particles that are collected by the control devices.

The extent of capture of these pollutants has not been quantified since some may vaporize from the control device wastewater stream and be reemitted to the atmosphere. Therefore, actual net removal efficiencies are unknown, and no estimates of annual emissions and emission reductions are given for phenol and formaldehyde.

7.1.1.2 Dispersion Analysis. Dispersion modeling was used to predict the contribution by wool fiberglass insulation production facilities to the ambient particulate concentration. The dispersion model used and the results obtained are discussed in the following subsections.

7.1.1.2.1 Model description. The model used in this dispersion analysis was the Industrial Source Complex (ISC) model in the short-term mode (ICST).[2,3] General modeling data of the ISC model are presented in

Table 7-9. The ISC model requires input data on sources, meteorology, and receptors. These items are discussed in the following subsections.

Source data. The three emission sources considered in this document for both RS and FA production lines are the forming, curing, and cooling sections. In this modeling effort, emissions were considered to be gaseous, i.e., as though the particles in the emission streams would not settle out. Because most of the gas streams are saturated with water and the particulate matter consists of sticky particles whose size distribution cannot be determined, particle settling was not considered in the modeling runs.

The following data are required by the ISC model for each production line and regulatory alternative:

1. Emission height, in meters (m);
2. Exit dimensions, in meters (m);
3. Exit velocity, in meters per second (m/s);
4. Exit temperature, in kelvins (K); and
5. Particulate emission rate, in grams per second (g/s).

Table 7-10 summarizes the source characteristics of each RS and FA model line addition and regulatory alternative (as described in Chapter 6). Table 7-11 summarizes the source characteristics of each RS model plant and regulatory alternative.

Meteorological data. Meteorological data required by the ISC model include the following hourly values for an entire year:

1. Ambient temperature, K;
2. Wind speed, m/s;
3. Wind direction to the nearest 10 degrees; and
4. Stability class.

Daily morning and afternoon mixing height data are also required and are interpolated internally in the ISC model to hourly values.

Wool fiberglass insulation facilities were assumed to be located in rural areas and, therefore, did not include heat island effects.

In this study, 1964 climatological data were compared for Kansas City, Missouri; Dayton, Ohio; Atlanta, Georgia; and Philadelphia, Pennsylvania. Climatological data from 1964 were used because they are fairly complete on an hour-by-hour basis and are considered meteorologically

TABLE 7-9. GENERAL MODELING DATA[4]

Type of data	Description
Meteorological Data	
Geographic terrain	Uniform Rolling Valley
Setting	Rural
Receptor Data	
Plant boundaries	Source(s) may be as close as 30 meters (100 feet) from plant boundary
	Radial distances of 0.3, 0.8, 1.0 and 3.0 kilometers (985; 1,640; 2,625; 3,280; and 9,840 feet) from the center of the modeled source(s) based on analysis of location of maximum (worst-case) ground level concentrations
Source Data	
Pollutant	Particulate (EPA Method 5E)
Particle size	Unmeasurable
Averaging times	Annual arithmetic and geometric mean concentrations
	Highest second-highest 24-hour concentrations
Special considerations	Downwash of the plume in the wake of a nearby building (height = 15 meters [50 feet])

TABLE 7-10a. SUMMARY OF SOURCE DATA FOR ROTARY SPIN AND FLAME ATTENUATION MODEL LINE ADDITIONS[4] (Metric)

Case	Line size + type[a,b]	Reg. Alt.	Stack No.[c]	Stack height, m	Stack diameter, m	Exit velocity, m/s	Exit temp., K	Emission rate, g/s
8	Medium RS	I	1	30	1.8	19	311	15.74
			2	30	1.2	19	533	2.99
			3	23	0.5	21	311	0.18
10	Medium RS	II	1	30	1.8	19	308	3.17
			2	30	1.2	19	533	2.99
			3	23	0.5	21	311	0.18
12	Medium RS	III	4	30	2.0	20	308	3.47
			5	23	0.5	21	311	0.18
14	Medium RS	IV	6	30	2.1	19	308	3.47
15	Large RS	I	1	30	2.0	21	311	22.78
			2	30	1.2	19	533	4.33
			3	23	0.5	21	311	0.26
17	Large RS	II	1	30	2.0	21	308	4.59
			2	30	1.2	19	533	4.33
			3	23	0.5	21	311	0.26
19	Large RS	III	4	30	2.1	22	308	5.02
			5	23	0.5	21	311	0.26
21	Large RS	IV	6	30	2.3	20	308	5.02
22	Small FA	I	1	30	2.1	19	339	6.99
			2	30	0.6	24	450	0.42
			3	23	0.4	21	311	0.05
23	Small FA	II	1	30	2.1	19	339	6.99
			2	30	0.6	18	333	0.09
			3	23	0.4	21	311	0.05
24	Small FA	III	4	30	2.1	19	339	6.99
			5	30	0.8	17	333	0.09
25	Small FA	IV	1	30	2.1	18	333	1.39
			2	30	0.6	24	450	0.42
			3	23	0.4	21	311	0.05

[a] RS = rotary spin process. FA = flame attenuation process.

[b] Source data for RS small line are the same as source data for small model plant (Table 7-11).

[c] Stack number refers to the individual point sources within the model line.

TABLE 7-10b. SUMMARY OF SOURCE DATA FOR ROTARY SPIN AND FLAME ATTENUATION MODEL LINE ADDITIONS[4]
(English)[a]

Case	Line size + type[b,c]	Reg. Alt.	Stack No.[d]	Stack height, ft	Stack diameter, ft	Exit velocity, ft/s	Exit temp., °F	Emission rate, lb/h
8	Medium RS	I	1	100	5.9	62	100	124.56
			2	100	3.9	62	500	23.76
			3	75	1.6	69	100	1.44
10	Medium RS	II	1	100	5.9	62	95	25.16
			2	100	3.9	62	500	23.73
			3	75	1.6	69	100	1.43
12	Medium RS	III	4	100	6.6	66	95	27.54
			5	75	1.6	69	100	1.43
14	Medium RS	IV	6	100	6.9	62	95	27.54
15	Large RS	I	1	100	6.6	69	100	180.36
			2	100	3.9	62	500	34.20
			3	75	1.6	69	100	2.16
17	Large RS	II	1	100	6.6	69	95	36.43
			2	100	3.9	62	500	34.20
			3	75	1.6	69	100	2.16
19	Large RS	III	4	100	6.9	72	95	39.85
			5	75	1.6	69	100	2.16
21	Large RS	IV	6	100	7.5	66	95	39.85
22	Small FA	I	1	100	6.9	62	150	55.44
			2	100	2.0	79	350	3.24
			3	75	1.3	69	100	0.36
23	Small FA	II	1	100	6.9	62	150	55.44
			2	100	2.0	59	140	0.72
			3	75	1.3	69	100	0.36
24	Small FA	III	4	100	6.9	62	150	55.44
			5	100	2.6	56	140	0.72
25	Small FA	IV	1	100	6.9	59	140	11.16
			2	100	2.0	79	350	3.24
			3	75	1.3	69	100	0.36

[a] Metric and English units may not convert exactly due to independent rounding.

[b] RS = rotary spin process. FA = flame attenuation process.

[c] Source data for RS small line are the same as source data for small model plant (Table 7-11).

[d] Stack number refers to the individual point sources within the model line.

TABLE 7-11a. SUMMARY OF SOURCE DATA FOR ROTARY SPIN MODEL PLANTS[10] (Metric)

Case	Line size[a]	Reg. Alt.	Stack No.[b]	Stack height, m	Stack diameter, m	Exit velocity, m/s	Exit temp., K	Emission rate, g/s
26	Small	I	1	30	1.7	20	311	8.28
			2	30	1.2	19	533	1.58
			3	23	0.5	21	311	0.09
28	Small	II	3	23	0.5	21	311	0.09
			4	30	1.7	20	308	1.67
			5	30	1.2	19	533	1.58
30	Small	III	3	23	0.5	21	311	0.09
			6	30	1.9	20	308	1.83
32	Small	IV	7	30	2.0	20	308	1.83
33	Medium	I	1,2	23	0.5	21	311	0.26
			3	23	0.4	21	311	0.02
			4,5	30	1.2	19	533	4.33
			6	30	0.4	24	533	0.39
			7,8	30	2.0	21	311	22.78
			9	30	1.1	20	311	2.07
35	Medium	II	1,2	23	0.5	21	311	0.26
			3	23	0.4	21	311	0.02
			10,11	30	1.2	19	533	4.33
			12	30	0.4	24	533	0.39
			13,14	30	2.0	21	308	4.59
			15	30	1.1	20	308	0.42
37	Medium	III	1,2	23	0.5	21	311	0.26
			3	23	0.4	21	311	0.02
			16	30	1.1	22	308	0.46
			17,18	30	2.1	22	308	5.02
39	Medium	IV	19	30	1.2	19	308	0.46
			20,21	30	2.3	20	308	5.02
40	Large	I	1	23	0.5	21	311	0.09
			2	23	0.5	21	311	0.18
			3,4	23	0.5	21	311	0.26
			5	30	1.2	19	533	1.58
			6	30	1.2	19	533	2.99
			7,8	30	1.2	19	533	4.33
			9	30	1.7	20	311	8.28
			10	30	1.8	19	311	15.74
			11,12	30	2.0	21	311	22.78
42	Large	II	1	23	0.5	21	311	0.09
			2	23	0.5	21	311	0.18
			3,4	23	0.5	21	311	0.26
			13	30	1.2	19	533	1.58
			14	30	1.2	19	533	2.99
			17,18	30	1.2	19	533	4.33
			15	30	1.7	20	308	1.67
			16	30	1.8	19	308	3.17
			19,20	30	2.0	21	308	4.59
44	Large	III	1	23	0.5	21	311	0.09
			2	23	0.5	21	311	0.18
			3,4	23	0.5	21	311	0.26
			21	30	1.9	20	308	1.82
			22	30	2.0	20	308	3.47
			23,24	30	2.1	22	308	5.02
46	Large	IV	25	30	2.0	20	308	1.83
			26	30	2.1	19	308	3.47
			27,28	30	2.3	20	308	5.02

[a] Source data for RS small line are the same as source data for small model plant.
[b] Stack number refers to the individual point sources within the model plant.

TABLE 7-11b. SUMMARY OF SOURCE DATA FOR ROTARY SPIN MODEL PLANTS[10] (English)[a]

Case	Line size[b]	Reg. Alt.	Stack No.[c]	Stack height, ft	Stack diameter, ft	Exit velocity, ft/s	Exit temp., °F	Emission rate, lb/h
26	Small	I	1	100	5.6	66	100	65.52
			2	100	3.9	62	500	12.60
			3	75	1.6	69	100	0.72
28	Small	II	3	75	1.6	69	100	0.72
			4	100	5.6	66	95	26.28
			5	100	3.9	62	500	12.60
30	Small	III	3	75	1.6	69	100	0.72
			6	100	6.2	66	95	13.26
32	Small	IV	7	100	6.6	66	95	12.54
33	Medium	I	1,2	75	1.6	69	100	2.16
			3	75	1.3	69	100	0.14
			4,5	100	3.9	62	500	34.20
			6	100	1.3	79	500	3.24
			7,8	100	6.6	69	100	180.36
			9	100	3.6	66	100	16.56
35	Medium	II	1,2	75	1.6	69	100	2.16
			3	75	1.3	69	100	0.14
			10,11	100	3.9	62	500	34.20
			12	100	1.3	79	500	3.24
			13,14	100	6.6	69	95	36.43
			15	100	3.6	66	95	3.33
37	Medium	III	1,2	75	1.6	69	100	2.16
			3	75	1.2	69	100	0.14
			16	100	3.6	72	95	3.65
			17,18	100	6.9	92	95	39.85
39	Medium	IV	19	100	3.9	62	95	3.65
			20,21	100	7.5	66	95	39.85
40	Large	I	1	75	1.6	69	100	0.72
			2	75	1.6	69	100	1.44
			3,4	75	1.6	69	100	2.16
			5	100	3.9	62	500	12.60
			6	100	3.9	62	500	23.76
			7,8	100	3.9	62	500	34.20
			9	100	5.6	66	100	65.52
			10	100	5.9	62	100	124.56
			11,12	100	6.6	69	100	180.36
42	Large	II	1	75	1.6	69	100	0.72
			2	75	1.6	69	100	1.44
			3,4	75	1.6	69	100	2.16
			13	100	3.9	62	500	12.60
			14	100	3.9	62	500	23.76
			17,18	100	3.9	62	500	34.20
			15	100	5.6	66	98	13.26
			16	100	5.9	62	98	25.16
			19,20	100	6.6	69	98	36.43
44	Large	III	1	75	1.6	69	100	0.72
			2	75	1.6	69	100	1.44
			3,4	75	1.6	69	100	2.16
			21	100	6.2	66	98	14.53
			22	100	6.6	66	98	27.54
			23,24	100	6.9	72	98	39.85
46	Large	IV	25	100	6.6	66	98	14.53
			26	100	6.9	62	98	27.54
			27,28	100	7.5	66	98	39.85

[a] Metric and English units may not convert exactly due to independent numerical rounding.
[b] Source data for RS small line are the same as source data for small model plant.
[c] Stack number refers to the individual point sources within the model plant.

representative. The selection of these meterological data sets was based on the geographic concentration of wool fiberglass insulation plants. Therefore, the four meteorological data sets chosen for comparison are considered to be representative of the four greatest concentrations of wool fiberglass insulation plants.

The selection of the meteorological data set ultimately used in the modeling analysis was based on the comparison of all-stability and individual-stability wind runs developed for each of the four meteorological data sets and on a set of preliminary ISC runs carried out with one of the modeling cases used as input to each of the four meteorological data sets. From the comparison of the four data sets, the Dayton, Ohio, meteorological data set was selected for use in the modeling analysis for the following reasons:

1. The occurrence of the highest 24-hour total suspended particulate (TSP) concentration;
2. The occurrence of the highest second-highest 24-hour TSP concentration;
3. The negligible influence of calms on concentration maxima;
4. The relatively centralized location of the station in relation to many of the wool fiberglass insulation plants;
5. The specific geographical association with six wool fiberglass insulation plants in Ohio and Indiana; and
6. The relatively similar broad characteristics of the joint frequency distributions with the Kansas City, Missouri, and Philadelphia, Pennsylvania, data sets.

Receptor locations. The ISC model calculates concentration impacts for receptors at specified radial distances from the center of the source. Receptors were located at distances of 300, 500, 800, 1,000, and 3,000 meters (985, 1,640, 2,625, 3,280, and 9,840 feet). All receptors were assumed to be at the same elevation as plant grade. The only terrain effects included in the modeling were those implicitly contained in the meteorological data.

7.1.1.2.2 Discussion of dispersion calculations. The ISC model was run using as input the Dayton (1964) surface meteorological data set. Hourly concentration impacts from each of the 24 modeling cases were calculated by the ISC model. Concentrations were summed for each 24-hour period. Annual arithmetic mean concentrations were then calculated by the model for each receptor; there was no attempt to calculate the annual geometric mean concentrations, which are usually in the range of 75 to 95 percent of the annual arithmetic mean concentrations.

Concentration estimates calculated by the ISC model are typically within a factor of 2 of measured ambient concentrations.

The modeled particulate matter concentration impacts can be compared to the National Ambient Air Quality Standards (NAAQS):

Averaging time	Standard type	Particulate concentration, μg/m³
Annual geometric mean	Primary	75
	Secondary	60
24-hour maximum (not to be exceeded more than once per year)	Primary	260
	Secondary	150

7.1.1.2.3 Annual concentration impacts. Maximum annual arithmetic mean TSP concentrations calculated by the ISC model are presented in Table 7-12 for each of the regulatory alternatives for RS insulation model plants and lines. The maximum annual arithmetic mean concentrations for Regulatory Alternatives II through IV range from 0.96 to 2.26 μg/m³ for RS model lines and from 0.51 to 6.95 μg/m³ for RS model plants. Baseline maximum annual arithmetic mean concentrations are from 5.38 to 6.14 μg/m³ for RS model lines and from 2.83 to 20.37 μg/m³ for RS model plants. The highest maximum concentration occurred for the baseline Case 40 with an impact of 20.37 μg/m³. If one assumes a pristine environment and compares these levels with the NAAQS, which are expressed as geometric mean rather than arithmetic mean, this calculated maximum is less than 27 percent of the primary standard and less than 34 percent of the secondary standard.

7.1.1.2.4 Twenty-four hour maximum concentration impacts. Maximum 24-hour and highest second-highest 24-hour TSP concentrations calculated with ISC and the Dayton, Ohio, (1964) meteorological data are also presented in Table 7-12 for each of the regulatory alternatives for wool

TABLE 7-12. SUMMARY OF MAXIMUM TSP CONCENTRATION IMPACTS[4]

Case	Line type + Reg. Alt.	Maximum annual arithmetic mean, μg/m^3	Distance from source center to receptor, m	Maximum 24-hour average TSP concentrations, μg/m^3	Distance from source center to receptor, m	Highest second-highest 24-hour average TSP concentrations, μg/m^3	Distance from source center to receptor, m
8	I, RS	5.38	800	78.18	300	49.04	500
10	II, RS	1.79	800	24.78	300	18.58	300
12	III, RS	1.14	800	15.08	300	9.33	300
14	IV, RS	0.96	1,000	13.39	500	7.84	1,000
15	I, RS	6.14	1,000	68.30	500	48.77	500
17	II, RS	2.26	1,000	28.85	300	23.14	300
19	III, RS	1.44	1,000	14.35	800	11.59	1,000
21	IV, RS	1.09	1,000	12.54	800	9.50	1,000
22	I, FA	1.10	1,000	17.70	300	13.91	300
23	II, FA	0.98	1,000	16.31	300	12.04	300
24	III, FA	0.93	1,000	16.09	300	11.70	300
25	IV, FA	0.33	1,000	4.03	500	3.55	300
26	I, RS	2.83	800	41.11	300	25.78	500
28	II, RS	0.94	800	13.02	300	9.74	300
30	III, RS	0.65	800	7.92	300	5.23	500
32	IV, RS	0.51	1,000	7.07	500	4.14	1,000
33	I, RS	13.44	800	142.10	500	104.70	500
35	II, RS	5.02	800	63.17	300	50.78	300
37	III, RS	3.04	1,000	30.28	500	23.95	1,000
39	IV, RS	2.41	1,000	26.74	800	20.42	1,000
40	I, RS	20.37	800	233.91	500	172.37	500
42	II, RS	6.95	800	89.87	300	73.87	300
44	III, RS	4.55	1,000	48.01	500	34.81	1,000
46	IV, RS	3.66	1,000	41.88	500	30.97	1,000

fiberglass insulation model plants and lines. The highest second-highest 24-hour concentrations for Regulatory Alternatives II through IV range from 9.5 to 23.14 μg/m^3 for RS model lines and from 4.14 to 73.87 μg/m^3 for RS model plants. Baseline highest second-highest 24-hour concentrations are from 48.77 to 49.04 μg/m^3 for model lines and 25.78 to 172.37 μg/m^3 for model plants. The highest second-highest 24-hour concentration occurred for the baseline Case 40 with an impact of 172.37 μg/m^3. This value is approximately 66 percent of the primary NAAQS and approximately 115 percent of the secondary NAAQS.

7.1.2 Secondary Air Impacts

Secondary emissions of air pollutants result from generation of the energy required to operate the control devices. Generation of the electric power required to operate the control devices will result in particulate, sulfur dioxide (SO_2), and oxides of nitrogen (NO_x) emissions from the electric power generator. Natural gas combusted in incinerators used to control curing emissions will result in NO_x emissions from the wool fiberglass insulation manufacturing plant.

Secondary emissions were calculated assuming that electric power to the control devices was supplied by a coal-fired power plant. It was assumed that the power plant complies with the standards of performance for electric utility steam generating units.[5] The applicable standards limit particulate emissions to 0.03 lb/million Btu heat input, SO_2 emissions to 1.20 lb/million Btu heat input, and NO_x emissions to 0.60 lb/million Btu heat input.[5] Secondary emissions were calculated using these emission limits.[1] For Regulatory Alternatives II through IV, the secondary particulate emissions above baseline from the electric power generator range from 0.06 to 0.34 Mg/yr (0.06 to 0.38 tons/yr) for RS model lines, 0.16 to 1.23 Mg/yr (0.18 to 1.37 tons/yr) for RS model plants, and 0.11 to 0.91 Mg/yr (0.12 to 1.00 tons/yr) for the FA model line. Secondary emissions of SO_2 above baseline range from 2.40 to 13.75 Mg/yr (2.64 to 15.16 tons/yr) for RS model lines, 6.45 to 49.54 Mg/yr (7.11 to 54.62 tons/yr) for RS model plants, and 4.51 to 36.43 Mg/yr (4.97 to 40.16 tons/yr) for the FA model line. The secondary NO_x emissions above baseline range from 1.20 to 6.87 Mg/yr (1.33 to 7.58 tons/yr) for RS model lines, 3.22 to 24.77 Mg/yr (3.56 to 27.31 tons/yr) for RS model plants, and 2.25 to 18.22 Mg/yr (2.48 to 20.08 tons/yr) for the FA model line.

Emissions caused by the generation of energy for the control devices are small compared to the emission reduction from the model lines and plants presented in Section 7.1.1 and compared to the total emissions from the power generator. For example, a large model line controlled to emission levels represented by Regulatory Alternative IV would indirectly increase emissions from a steam generator and would reduce the net particulate matter reduction by less than 1 percent.

7.2 WATER POLLUTION IMPACTS

Water pollution impacts can result from the application of air pollution control devices on wool fiberglass insulation manufacturing lines. Most of the devices used to control particulate emissions from fiberglass plants produce aqueous discharges. Wastewater from these control devices is alkaline (pH >7.0) and contains phenols, other dissolved organic compounds, and dissolved and suspended solids.[6] Typically, water treatment consists of screening and settling of the wastewater to remove suspended solids. At some facilities, wastewater is also flocculated and filtered.

For the wool fiberglass insulation manufacturing industry, the effluent guidelines for best available technology for all existing facilities allow no discharge of process wastewaters into navigable waterways.[7] Until this requirement takes effect in 1984, existing facilities are allowed to discharge wastewater from advanced air pollution control devices when the water cannot be consumed in the process.[7,8] Effluent limitations for such discharges have been specified.[7] Pretreatment requirements at existing facilities for the discharge of process wastewaters into publicly owned treatment works (POTW's) have not been specified at this time.

Standards of performance for new sources (as determined under the Clean Water Act) allow no discharge of process wastewaters into navigable waterways.[7] Pretreatment standards for new sources allow no discharge of incompatible pollutants (e.g., phenol) into POTW's. This effectively precludes wool fiberglass companies from discharging process wastewaters into POTW's. Thus, no impact on water quality is expected because by 1984 both existing and new sources should produce zero wastewater discharges.

7.3 SOLID WASTE DISPOSAL IMPACTS

Solid wastes from control devices at wool fiberglass insulation manufacturing plants consist of sludges and discarded HVAF filters. In this section, the solid waste impacts of the regulatory alternatives are discussed.

7.3.1 Solid Waste Quantities and Characteristics

Sludges produced by the control devices consist of glass fiber-resin masses in various stages of cure, glass fibers, phenols and other organic compounds, and water. Solid wastes from HVAF's consist of discarded filters and the collected glass fiber-resin masses and condensed resin materials.

Tables 7-13 and 7-14 give the quantities of solid waste generated and the incremental increase over baseline for each regulatory alternative. The estimates of solid waste are based on the amount of particulate matter collected and do not include the mass of water associated with the sludges or the mass of the discarded filter media from HVAF's. The national solid waste increase over baseline levels in the fifth year after proposal will range from 9,400 to 11,600 Mg/yr (10,400 to 12,800 tons/yr) for RS Regulatory Alternatives II through IV.

7.3.2 Solid Waste Disposal Methods

Discarded HVAF filters and control device sludges are disposed of by landfilling. Whether the wastes are treated before disposal depends on disposal costs, State and local regulations governing disposal, and requirements of the disposal facility. Treatment methods may include bagging of HVAF filters and dewatering and stabilizing of sludges.

7.3.3 Solid Waste Disposal Regulations

Solid wastes from the wool fiberglass insulation manufacturing industry presently are not classified as hazardous wastes under the regulations adopted to implement the Resource Conservation and Recovery Act (RCRA).[9] Thus, disposal of these wastes is governed by Section 4004 of RCRA and by the regulatory requirements of the States.[10]

TABLE 7-13. SOLID WASTE IMPACTS FOR ROTARY SPIN MODEL LINES AND PLANTS[a] [1]

	Regulatory Alternative								
	Uncon-trolled	I[b]		II		III		IV	
		Mg/yr	tons/yr	Mg/yr	tons/yr	Mg/yr	tons/yr	Mg/yr	tons/yr
Model Lines									
Small									
Total	0	239	263	429	473	470	518	473	521
Incremental[c]	--	--	--	190	210	231	255	234	258
Medium									
Total	0	453	499	815	898	892	984	898	990
Incremental	--	--	--	362	399	439	485	445	491
Large									
Total	0	656	723	1,180	1,301	1,293	1,425	1,300	1,433
Incremental	--	--	--	520	578	637	702	644	710
Model Plants									
1									
Total	0	239	263	429	473	470	518	473	521
Incremental	--	--	--	190	210	231	255	234	258
2									
Total	0	1,372	1,512	2,467	2,720	2,701	2,980	2,718	2,996
Incremental	--	--	--	1,095	1,208	1,329	1,468	1,346	1,484
3									
Total	0	2,004	2,208	3,604	3,973	3,984	4,352	3,971	4,377
Incremental	--	--	--	1,600	1,765	1,944	2,144	1,967	2,169

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[a] Does not include water associated with precipitator and scrubber sludges or discarded HVAF filters.
Metric and English figures may not convert exactly due to independent numerical rounding.
[b] Baseline.
[c] Incremental over baseline.

TABLE 7-14. SOLID WASTE IMPACTS FOR FLAME ATTENUATION MODEL LINE[a] [1]

Line designation	Regulatory Alternative						
	I[b]	II		III		IV	
		Mg/yr[b]	tons/yr	Mg/yr	tons/yr	Mg/yr	tons/yr
Small							
Total	0	10	11	11	12	161	178
Incremental[c]	--	10	11	11	12	161	178

[a] Does not include discarded HVAF filters. Metric and English units may not convert exactly due to independent numerical rounding.

[b] Baseline.

[c] Incremental over baseline.

7.4 ENERGY IMPACTS

7.4.1 Energy Consumption of Control Alternatives

Operation of wet ESP's, scrubbers, and HVAF's to control particulate emissions requires the use of electrical energy. The electricity is used to operate fans to move air and pumps to circulate water in the control devices. For wet ESP's, electricity is also used to create the corona discharge. Furthermore, incinerators used to control curing emissions use natural gas as fuel.

Tables 7-15 and 7-16 show the annual energy demand associated with each regulatory alternative. The electrical energy demands are expressed in terajoules (TJ) (10^{12} J)/yr and 10^9 Btu/yr. Table 7-17 shows the annual natural gas demand associated with Regulatory Alternatives I and II for RS model lines and plants. Tables 7-18 shows the total annual energy demand for each regulatory alternative for a typical RS model line and plant.

Comparison of the electrical energy demand of the alternatives shows that energy consumption varies with the devices used to control particulate emissions as well as with the plant or line size (gas volume). That is, for the same line or plant and level of control, a wet ESP uses less electricity to control emissions than does a venturi scrubber or HVAF. Therefore, the application of additional control above the baseline level may not significantly increase the electrical energy demand of fiberglass manufacturing facilities. The impact of RS Regulatory Alternatives II through IV on increased national electrical energy demand in the fifth year after proposal will range from 120 to 184 TJ/yr (1.13×10^{11} to 1.74×10^{11} Btu/yr).

Comparison of the total energy demand of each regulatory alternative shows that energy consumption for Alternatives I and II is greater than for Alternatives III and IV because Alternatives I and II require the use of incinerators to control particulate emissions while Alternatives III and IV do not. Incinerators require energy in the form of natural gas to perform combustion. Consequently, the alternatives that require the use of incinerators will show an increased energy demand because of the natural gas requirement. The impact of the regulatory alternatives on

TABLE 7-15. ELECTRICAL ENERGY REQUIREMENTS OF CONTROL EQUIPMENT FOR ROTARY SPIN MODEL LINES AND PLANTS[1]

	Regulatory Alternative			
	I[a]	II	III	IV
Model Line				
Small				
Total, TJ/yr[b]	5.25	9.41	11.35	12.15
10^9 Btu/yr	4.98	8.93	10.77	11.52
Incremental,[c] TJ/yr	--	4.16	6.09	6.89
10^9 Btu/yr	--	3.95	5.79	6.54
Medium				
Total, TJ/yr	5.61	10.21	12.15	12.95
10^9 Btu/yr	5.32	9.68	11.52	12.28
Incremental, TJ/yr	--	4.60	6.57	7.34
10^9 Btu/yr	--	4.36	6.23	6.96
Large				
Total, TJ/yr	6.86	13.00	14.93	15.73
10^9 Btu/yr	6.50	12.33	14.16	14.92
Incremental, TJ/yr	--	6.14	8.09	8.87
10^9 Btu/yr	--	5.83	7.66	8.42
Model Plant				
1				
Total, TJ/yr	5.25	9.41	11.35	12.15
10^9 Btu/yr	4.98	8.93	10.77	11.52
Incremental, TJ/yr	--	4.16	6.09	6.89
10^9 Btu/yr	--	3.95	5.79	6.54
2				
Total, TJ/yr	16.01	29.83	33.66	35.66
10^9 Btu/yr	15.17	28.30	31.93	33.82
Incremental, TJ/yr	--	13.82	17.65	19.65
10^9 Btu/yr	--	13.13	16.76	18.65
3				
Total, TJ/yr	24.58	45.62	53.36	56.56
10^9 Btu/yr	23.30	43.27	50.61	53.64
Incremental, TJ/yr	--	21.04	28.84	31.98
10^9 Btu/yr	--	19.97	27.31	30.34

[a] Baseline.

[b] Metric and English units may not convert exactly due to independent rounding.

[c] Incremental over baseline.

TABLE 7-16. ELECTRICAL ENERGY REQUIREMENTS OF CONTROL EQUIPMENT FOR FLAME ATTENUATION MODEL LINE[1]

Line designation	Regulatory Alternative	Energy demand[b] TJ/yr	Energy demand[b] 10^9 Btu/yr
Small	I[a]	0	0
	II	2.91	2.76
	III	3.74	3.54
	IV	23.53	22.31

[a] Baseline.

[b] Metric and English units may not convert exactly due to independent rounding.

TABLE 7-17. NATURAL GAS DEMAND OF CONTROL EQUIPMENT ON ROTARY SPIN MODEL LINES AND PLANTS[1]

	Regulatory Alternative[a]	
	I[b]	II
Model Lines		
Small		
Total, 10^6 m^3/yr[c]	3.0	3.0
10^6 ft^3/yr	104	104
Incremental,[d] 10^6 m^3/yr	--	0
10^6 ft^3/yr		0
Medium		
Total, 10^6 m^3/yr	3.0	3.0
10^6 ft^3/yr	104	104
Incremental, 10^6 m^3/yr	--	0
10^6 ft^3/yr	--	0
Large		
Total, 10^6 m^3/yr	3.0	3.0
10^6 ft^3/yr	104	104
Incremental, 10^6 m^3/yr	--	0
10^6 ft^3/yr	--	0
Model Plants		
1		
Total, 10^6 m^3/yr	3.0	3.0
10^6 ft^3/yr	104	104
Incremental, 10^6 m^3/yr	--	0
10^6 ft^3/yr	--	0
2		
Total, 10^6 m^3/yr	6.3	6.3
10^6 ft^3/yr	221	221
Incremental, 10^6 m^3/yr	--	0
10^6 ft^3/yr	--	0
3		
Total, 10^6 m^3/yr	11.8	11.8
10^6 ft^3/yr	417	417
Incremental, 10^6 m^3/yr	--	0
10^6 ft^3/yr	--	0

[a] All other regulatory alternatives do not include incinerators.
[b] Baseline.
[c] Metric and English units may not convert exactly due to independent rounding.
[d] Incremental over baseline.

TABLE 7-18. TOTAL ENERGY DEMAND OF CONTROL EQUIPMENT ON A TYPICAL ROTARY SPIN MODEL LINE AND PLANT[1]

	Regulatory Alternative			
	I[a]	II	III	IV
Model Line				
Electricity, TJ/yr[b]	5.61	10.21	12.15	12.95
10^9 Btu/yr	5.32	9.68	11.52	12.28
Natural gas, TJ/yr	61.82	61.82	0	0
10^9 Btu/yr	58.88	58.88	0	0
Total, TJ/yr	67.43	72.03	12.15	12.95
10^9 Btu/yr	64.20	68.56	11.52	12.28
Incremental, TJ/yr[c]	--	+4.60	-55.28	-54.48
10^9 Btu/yr	--	+4.36	-52.68	-51.92
Medium Plant				
Electricity, TJ/yr	16.01	29.83	33.66	35.66
10^9 Btu/yr	15.17	28.30	31.93	33.82
Natural gas, TJ/yr	131.37	131.37	0	0
10^9 Btu/yr	125.12	125.12	0	0
Total, TJ/yr	147.38	161.20	33.66	35.66
10^9 Btu/yr	140.29	153.42	31.93	33.82
Incremental, TJ/yr[c]	--	+13.82	-113.72	-111.72
10^9 Btu/yr	--	+13.13	-108.36	-106.47

[a] Baseline.

[b] TJ/yr x (9.524×10^8) = 10^9 Btu/yr. Conversion to English units was done with unrounded final metric units. Metric and English units may not convert exactly due to independent rounding.

[c] Incremental increase or decrease relative to baseline.

national total energy demand in the fifth year ranges from an increase of 120 TJ/yr (1.13×10^{11} Btu/yr) for Alternative II to a decrease of up to 1,280 TJ/yr (1.21×10^{12} Btu/yr) for Alternative III relative to the baseline.

7.5 OTHER ENVIRONMENTAL IMPACTS

A fiberglass plant generates substantial noise, particularly in the forming area. The additional noise introduced by air pollution control devices will not significantly increase the noise levels.

7.6 OTHER ENVIRONMENTAL CONCERNS

7.6.1 Irreversible and Irretrievable Commitment of Resources

As discussed in Section 7.4, the regulatory alternatives will result in an increase in the irreversible and irretrievable commitment of energy resources. However, this increased energy demand for pollution control is insignificant compared to total line and plant energy demand.

7.6.2 Environmental Impact of Delayed Standard

Based on the capacity growth projections presented in Chapter 9, a delay in proposal of the standard from 1983 to 1986 would reduce the controlled production capacity by 448,000 Mg (494,000 tons). Table 7-19 summarizes and compares the fifth-year emission reduction of a delayed standard with the emission reduction that would be achieved in the same year if the standard were proposed in 1983. As shown, the emission reductions in 1991 are decreased from 15,968 to 11,978 Mg (17,601 to 13,203 tons) under Regulatory Alternative II and from 19,614 to 14,713 Mg (21,620 to 16,218 tons) under Regulatory Alternative IV.

Since there is no water pollution impact and only negligible energy consumption impacts associated with the control alternatives, there is no significant benefit to be obtained from delaying the proposed standards. Furthermore, there does not appear to be any emerging emission control technology that could achieve greater emissions reduction or result in lower costs than that represented by the control devices considered here. Consequently, there are no benefits or advantages to delaying the proposed standards.

TABLE 7-19. ENVIRONMENTAL IMPACT OF DELAYED STANDARD--EMISSION REDUCTION IN 1991[a] [1]

Reg. alt.	Proposal in 1983		Proposal in 1986	
	Mg/yr[b]	tons/yr	Mg/yr	tons/yr
II	15,968	17,601	11,978	13,203
III	19,383	21,366	14,541	16,028
IV	19,614	21,620	14,713	16,218

[a] Baseline emissions in 1991 for the two cases are 24,600 Mg/yr (27,100 tons/yr) and 18,600 Mg/yr (20,500 tons/yr).

[b] English and metric figures may not convert exactly due to independent numerical rounding.

7.7 REFERENCES FOR CHAPTER 7

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8. COSTS

8.1 COST ANALYSIS OF REGULATORY ALTERNATIVES

The estimated cost impacts of implementing the regulatory alternatives for the new, modified, or reconstructed wool fiberglass insulation manufacturing model lines and plants described in Chapter 6 are presented in this chapter. The objective of this analysis is to quantify the cost impacts associated with various levels of control of particulate matter. The economic impact of the regulatory alternatives on wool fiberglass insulation manufacturers is presented in Chapter 9.

Capital and annualized costs are presented for the uncontrolled production facility and for the pollution control devices for the four regulatory alternatives. All costs are reported in January 1982 dollars.

8.1.1 New Facilities

Capital investment and annual operating and maintenance (O&M) costs were calculated for the wool fiberglass manufacturing model lines and plants for the alternative control methods. The cost calculations were performed using information supplied by industry and other sources of information. These sources are presented in Table 8-1.

The specifications presented in Tables 8-2 and 8-3 provide the bases for costing the model lines. Table 8-4 presents typical specifications for control devices currently used in the wool fiberglass insulation manufacturing industry. These specifications were used to evaluate the costs of the control devices. Table 8-5 presents the specifications used to evaluate costs of the model plants.

The model plants considered here include the wool fiberglass insulation production line (forming, curing, and cooling), in addition to the furnace, building, land, and any other integral equipment necessary for

TABLE 8-1. SUMMARY OF SOURCES OF COSTING INFORMATION

Costed item	Developing organization	Date(s)	Reference
Utilities	Industry	1981-1982	1
	Bureau of Labor Statistics	1982	2
Capital cost indices	McGraw-Hill, Inc.	1982	3, 4, 5
	GARD, Inc.	1978	6
Labor	Bureau of Labor Statistics	1982	7
Capital charges	GARD, Inc.	1978	8
Capital costs			
Wet ESP's	GARD, Inc.	1978	9
	United McGill Corp.	1981	10
HVAF's	Andersen 2000, Inc.	1981	11
Venturi scrubbers	GARD, Inc.	1978	12
Incinerators	GARD, Inc.	1978	13
	Shell Development Co.	1972	14
Water treatment	EPA	1975	15
	EPA	1978	16
Auxiliary equipment (ductwork, stack, etc.)	GARD, Inc.	1978	17
Production process	Industry	1981-1982	1
Cost factors	GARD, Inc.	1978	8

TABLE 8-2. MODEL LINE PARAMETERS--ROTARY SPIN

Line designation:	Specialty	Small	Medium	Large
1. Line information				
Annual production, Mg/yr[a]	4,500	18,000	34,000	50,000
tons/yr	5,000	20,000	38,000	55,000
Hours/year operation	8,000	8,000	8,000	8,000
Products	(PI, SP)[b]	—— (BI, PI, DB, HDI)[b] ——		
2. Process information				
A. Forming section				
Gas flow rate,[c] m^3/min	1,100	2,800	3,100	4,100
acfm	40,000	100,000	110,000	145,000
Gas temperature,[c] °C	52	52	52	52
°F	125	125	125	125
Moisture,[c] %	6	6	6	6
Uncontrolled particulate emissions,[d] kg/Mg	26	26	26	26
lb/ton	52	52	52	52
B. Curing section				
Gas flow rate,[c] m^3/min	140	1,100	1,100	1,100
acfm	5,000	40,000	40,000	40,000
Gas temperature,[c] °C	177	177	177	177
°F	350	350	350	350
Moisture,[c] %	6	6	6	6
Uncontrolled particulate emissions,[d] kg/Mg	3	3	3	3
lb/ton	5	5	5	5
C. Cooling section				
Gas flow rate,[c] m^3/min	140	280	280	280
acfm	5,000	10,000	10,000	10,000
Gas temperature,[c] °C	38	38	38	38
°F	100	100	100	100
Moisture,[c] %	2	2	2	2
Uncontrolled particulate emissions,[d,e] kg/Mg	0	0	0	0
lb/ton	0	0	0	0

[a] Mg/yr = megagrams per year.
m^3/min = cubic meters per minute.
acfm = actual cubic feet per minute.
kg/Mg = kilograms per megagram.
lb/ton = pounds per ton.

[b] BI = Building insulation. PI = Pipe insulation. DB = Ductboard.
HDI = Heavy density insulation. SP = Specialty.

[c] At the exit of each section of the process.

[d] Average total catch for all line sizes from EPA test data.

[e] Data less than 0.25 kg/Mg (0.5 lb/ton) round to zero.

TABLE 8-3. MODEL LINE PARAMETERS--FLAME ATTENUATION

Line designation:	Small
1. Line information	
Annual production, Mg/yr[a]	4,500
tons/yr	5,000
Hours/year operation	8,000
Products	(BI, PI, DB, SP, HDI)[b]
2. Process information	
A. Forming section	
Gas flow rate,[c] m^3/min	4,000
acfm	140,000
Gas temperature,[c] °C	66
°F	150
Moisture,[c] %	6
Uncontrolled particulate emissions,[d] kg/Mg	44
lb/ton	89
B. Curing section	
Gas flow rate,[c] m^3/min	420
acfm	15,000
Gas temperature,[c] °C	177
°F	350
Moisture,[c] %	6
Uncontrolled particulate emissions,[d] kg/Mg	3
lb/ton	5
C. Cooling section	
Gas flow rate,[c] m^3/min	140
acfm	5,000
Gas temperature,[c] °C	38
°F	100
Moisture,[c] %	2
Uncontrolled particulate emissions,[d,e] kg/Mg	1
lb/ton	1

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[a] Mg/yr = megagrams per year.
m^3/min = cubic meters per minute.
acfm = actual cubic feet per minute.
kg/Mg = kilograms per megagram.
lb/ton = pounds per ton.

[b] BI = Building insulation. PI = Pipe insulation. DB = Ductboard.
HDI = Heavy density insulation. SP = Specialty.

[c] At the exit of each section of the process.

[d] Based on highest total catch from EPA test data on FA lines.

[e] kg/Mg equal lb/ton due to numerical rounding.

TABLE 8-4. CONTROL DEVICE SYSTEM PARAMETERS AND SPECIFICATIONS

Parameter[a]	Specification
Venturi Scrubber	
Water spray rate, ℓ/min per 1,000 m^3/min (gpm/1,000 acfm)	2.0 (15)
Δp, Pa (in. w.c.)	
Regulatory Alternative I	1,245 (5)
Regulatory Alternatives II, III	8,710 (35)
Wet ESP	
Water spray rate, ℓ/min per 1,000 m^3/min (gpm/1,000 acfm)	1.3 (10)
Δp, Pa (in. w.c.)	250 (1)
Design efficiency, percent	90
Precipitation rate parameter, m/min (ft/min)	2.37 (7.78)
Specific collection area, m^2 per 1,000 m^3/min (ft^2/1,000 acfm)	0.98 (300)
Incinerator	
Residence time, s	0.5
Operating temperature, °C (°F)	
Regulatory Alternatives I, II	315 (600)
HVAF	
Water spray rate, ℓ/min per 1,000 m^3/min (gpm/1,000 acfm)	2.0 (15)
Δp, Pa (in. w.c.)	6,970 (28)

[a] ℓ/min per 1,000 m^3/min = liters per minute per 1,000 cubic meters per minute.
gpm/1,000 acfm = gallons per minute per 1,000 actual cubic feet per minute.
Pa = pascals.
in. w.c. = inches water column.
ft/min = feet per minute.

TABLE 8-5. MODEL PLANT PARAMETERS

Model plant No.	Plant type[a]	Plant building, 10^3 m^2 (ft^2)	Plant land area, 10^3 m^2 (acres)	Annual production capacity Mg/yr	(tons/yr)	Model line combination
1	RS	39 (420,000)	121 (30)	18,000	(20,000)	1 small
2	RS	56 (600,000)	162 (40)	104,500	(115,000)	2 large and 1 specialty
3	RS	70 (750,000)	202 (50)	152,000	(168,000)	1 small, 1 medium, and 2 large

[a] RS = rotary spin.

the production of wool fiberglass. Inclusion of the costs of these items in the plant costs is necessary to estimate properly the economic and capital availability impacts of the regulatory alternatives. The control device costs include the price of the control device itself as well as auxiliary equipment (such as fans, ductwork, stacks, and water screening) and the direct and indirect installation costs. Further explanation of the control device costs and their derivation may be found in the docket.[18]

8.1.1.1 Capital Costs--Model Lines. Tables 8-6 and 8-7 show the basis and methodology for developing capital cost estimates for uncontrolled wool fiberglass model lines and for the various control technologies.

The capital costs for model lines (forming, curing, and cooling sections) are presented in Table 8-8. Costs for uncontrolled model lines, each control system, and total model lines are given. Also included is the "normalized" total capital cost, which is calculated by dividing the total cost of the model line by the line production capacity. Normalized capital costs provide a measure of the capital investment required per unit of production capacity.

The last two columns in Table 8-8 present percent increases in the total model line capital cost. These percent increases are calculated with respect to: (a) uncontrolled model line capital costs, and (b) baseline controlled model line capital costs (cost of line and control method required under the baseline control alternative). (For the flame attenuation [FA] model line, the baseline is uncontrolled.)

For cases where a control device is used, the percentage increase in costs over the uncontrolled case provides a measure of the additional capital required to construct the control device(s). The percentage increase over the baseline case provides a measure of the additional capital required to meet emission limits more stringent than the emission limits established by existing regulations (baseline).

The percentage increase in capital cost over baseline ranges from 1.3 percent for a high pressure drop scrubber on forming and a low temperature incinerator on curing on a large rotary spin (RS) line (Regulatory Alternative II) to 71.6 percent for a high velocity air filter (HVAF) on forming on a small FA line (Regulatory Alternative IV).

TABLE 8-6. BASIS FOR ESTIMATING CAPITAL AND ANNUALIZED COSTS OF FIBERGLASS LINES[a]
(January 1982 Dollars)

Cost element	Costs, $/Mg ($/ton) of product (unless noted otherwise)			
	Rotary spin		Flame attenuation	
Capital costs (except pollution control equipment)[b]				
Total line (furnace and forming, curing, and cooling sections)	639	(580)	678	(615)
Forming, curing, cooling sections only	513	(465)	540	(490)
Building cost	420/m^2	(39/ft^2)	420/m^2	(39/ft^2)
Land cost	2.47/m^2	(10,000/ acre)	2.47/m^2	(10,000/ acre)
Direct Operating Costs				
1. Labor				
a. Operator (including maintenance) (19.7 h/Mg [17.9 h/ton], $8.58/h)	169.29	(153.58)	169.29	(153.58)
b. Supervisory (10 percent of 1a)	16.93	(15.36)	16.93	(15.36)
2. Raw material[c]				
a. Glass	106	(96)	106	(96)
b. Binder				
(1) Home insulation	67	(61)	67	(61)
(2) Pipe insulation	86	(78)	86	(78)
(3) Heavy density insulation	143	(130)	143	(130)
(4) Ductboard	143	(130)	143	(130)
3. Maintenance (replacement parts and supplies)	28	(25)	95	(86)
4. Utilities				
a. Electricity	82	(74)	95	(86)
b. Gas	122	(111)	147	(133)
c. Water	1.18	(1.07)	1.17	(1.06)
Indirect Operating Costs[d]				
5. Overhead (80%[1a+1b+3])	--		--	
6. Taxes (1% of capital cost)	--		--	
7. Insurance (1% of capital cost)	--		--	
8. Capital recovery cost[e] (10.608% of capital cost)	--		--	

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[a] Based on industry information.
[b] Updated using *Chemical Engineering* CE Plant Cost Index (Reference 4).
[c] Updated using *Chemical Engineering* CE Producer Prices, Industrial Chemicals Index (Reference 3).
[d] Based on Reference 8.
[e] Based on 10-percent interest for 30-year life.

TABLE 8-7. COMPONENT CAPITAL COST FACTORS AS A FUNCTION OF CONTROL EQUIPMENT COST--NEW FACILITIES[8]

Cost element	Cost factor		
	Wet ESP, HVAF	Scrubber	Incinerator
Direct costs			
1. Purchased equipment			
a. Control device	A		
b. Auxiliary equipment (ductwork, stack, fan system, etc.)	B		
c. Instruments and controls	0.10 (A+B)		
d. Taxes	0.03 (A+B)		
e. Freight	0.05 (A+B)		
Purchased equipment cost = 1.18 (A+B)	Q	Q	Q
2. Installation direct costs			
a. Foundation and supports	0.04Q	0.06Q	0.08Q
b. Handling and erection	0.50Q	0.40Q	0.14Q
c. Electrical	0.08Q	0.01Q	0.04Q
d. Piping	0.01Q	0.05Q	0.02Q
e. Insulation	0.02Q	0.03Q	0.01Q
f. Painting	0.02Q	0.01Q	0.01Q
Total installation direct costs (2a through 2f)	0.67Q	0.56Q	0.30Q
Total direct costs (1 plus 2)	1.67Q	1.56Q	1.30Q
Indirect costs			
3. Installation indirect costs			
a. Engineering and supervision	0.20Q	0.10Q	0.10Q
b. Construction and field expenses	0.20Q	0.10Q	0.05Q
c. Construction fee	0.10Q	0.10Q	0.10Q
d. Startup	0.01Q	0.01Q	0.02Q
e. Performance test	0.01Q	0.01Q	0.01Q
Total installation indirect costs (3a through 3e)	0.52Q	0.32Q	0.28Q
4. Contingencies	0.03Q	0.03Q	0.03Q
Total indirect costs (3 plus 4)	0.55Q	0.35Q	0.31Q
TOTAL CAPITAL COSTS	2.22Q	1.91Q	1.61Q

TABLE 8-8. CAPITAL COSTS OF MODEL FIBERGLASS LINES[a] 18

Reg. Alt.	Control equipment[b]	Capital costs: Uncontrolled line, $000[c]	Capital costs: Control equipment, $000[c]	Capital costs: Total, $000[c]	Normalized total[d]: $/Mg	Normalized total[d]: $/ton	Percent increase in costs: Over uncontrolled	Percent increase in costs: Over baseline
RS Small Line								
I[e]	Scrub., Inc.	9,300	1,017	10,317	573	516	10.9	0
II	Scrub., Inc.	9,300	1,269	10,569	587	528	13.6	2.4
	ESP, Inc.	9,300	2,328	11,628	646	581	25.0	12.7
III	Scrub., Scrub.	9,300	1,295	10,595	589	530	13.9	2.7
	ESP, ESP	9,300	2,575	11,875	660	594	27.7	15.1
IV	Scrub., Scrub., Scrub.	9,300	1,366	10,666	593	533	14.7	3.4
	ESP, ESP, ESP	9,300	2,702	12,002	667	600	29.1	16.3
RS Medium Line								
I[e]	Scrub., Inc.	17,670	1,065	18,735	551	493	6.0	0
II	Scrub., Inc.	17,670	1,340	19,010	559	500	7.6	1.5
	ESP, Inc.	17,670	2,454	20,124	592	530	13.9	7.4
III	Scrub., Scrub.	17,670	1,366	19,036	560	501	7.7	1.6
	ESP, ESP	17,670	2,702	20,372	599	536	15.3	8.7
IV	Scrub., Scrub., Scrub.	17,670	1,437	19,107	562	503	8.1	2.0
	ESP, ESP, ESP	17,670	2,828	20,498	603	539	16.0	9.4
RS Large Line								
I[e]	Scrub., Inc.	25,575	1,233	26,808	536	487	4.8	0
II	Scrub., Inc.	25,575	1,589	27,164	543	494	6.2	1.3
	ESP, Inc.	25,575	2,897	28,472	569	518	11.3	6.2
III	Scrub., Scrub.	25,575	1,615	27,190	544	494	6.3	1.4
	ESP, ESP	25,575	3,145	28,720	574	522	12.3	7.1
IV	Scrub., Scrub., Scrub.	25,575	1,687	27,262	545	496	6.6	1.7
	ESP, ESP, ESP	25,575	3,271	28,846	577	524	12.8	7.6
FA Small Line								
I[e]	None	2,450	0	2,450	544	490	0	0
II	HVAF	2,450	412	2,862	636	572	16.8	16.8
III	HVAF, HVAF	2,450	465	2,915	648	583	20.0	20.0
IV	HVAF	2,450	1,754	4,204	934	841	71.6	71.6

[a] RS = rotary spin. FA = flame attenuation.

[b] Scrub. = venturi scrubber. Inc. = incinerator. HVAF = high velocity air filter. ESP = wet electrostatic precipitator.

[c] January 1982 dollars; numbers shown are thousands of dollars.

[d] Normalized total is total capital cost divided by line capacity.

[e] Baseline.

The overall percent capital cost increase over baseline is typically greatest for the RS small line and least for the RS medium and large lines.

8.1.1.2 Capital Costs--Model Plants. Table 8-9 presents the capital costs for the three RS model plants. The information is presented in the same format as that used in Table 8-8. The increase in capital cost over baseline ranges from 0.8 percent for a high pressure drop wet scrubber on model plant No. 2 (Regulatory Alternative III) to 5.7 percent for a wet electrostatic precipitator (ESP) on model plant No. 1 (Regulatory Alternative IV) with approximately the same range found for all three model plants.

8.1.1.3 Annualized Costs--Model Lines. Table 8-10 shows the basis for developing annualized cost estimates for the various control technologies. Table 8-6 shows the basis for estimating annualized costs of the model lines. As shown in Table 8-10, the total annualized cost is the sum of the annual operation and maintenance costs and the annualized capital charges.

The capital recovery factors used in this study are based on an equipment life of 10 years (typical of information provided by industry) and an interest rate of 10 percent.[1] The 10 percent interest rate should not be considered as the actual cost of borrowing capital because this analysis is not intended to be an economic feasibility study. Rather, 10 percent was selected as a typical nominal rate of return on investment to provide a basis for calculation of capital recovery charges. The capital recovery factors used for the model line and control equipment are also presented in Table 8-10.

The total annualized costs (dollars per year) for uncontrolled wool fiberglass model lines, each control system, and the total annualized cost of model lines and controls are presented in Table 8-11 for the model lines. Percentage increases in annualized costs for the model lines over the uncontrolled case and the baseline case are also presented.

The percentage increase in annualized cost over baseline ranges from 0.3 percent for a high pressure drop scrubber on forming and curing on a small and medium RS line (Regulatory Alternative III) and a wet ESP on forming and curing on a medium RS line (Regulatory Alternative III)

TABLE 8-9. CAPITAL COSTS OF MODEL FIBERGLASS PLANTS[18]

		Capital costs					Percent increase in costs	
					Normalized total[c]			
Reg. Alt.	Control equipment[a]	Uncontrolled plant, $000[b]	Control equipment, $000[b]	Total, $000[b]	$/Mg	$/ton	Over uncontrolled	Over baseline
Model Plant No. 1								
I[d]	Scrub., Inc.	28,280	1,017	29,297	1,628	1,465	3.6	0
II	Scrub., Inc.	28,280	1,269	29,549	1,642	1,477	4.5	0.9
	ESP, Inc.	28,280	2,328	30,608	1,700	1,530	8.2	4.5
III	Scrub., Scrub.	28,280	1,295	29,575	1,643	1,479	4.6	0.9
	ESP, ESP	28,280	2,575	30,855	1,714	1,543	9.1	5.3
IV	Scrub., Scrub., Scrub.	28,280	1,366	29,646	1,647	1,482	4.8	1.2
	ESP, ESP, ESP	28,280	2,702	30,982	1,721	1,549	9.6	5.6
Model Plant No. 2								
I[d]	Scrub., Inc.	90,500	3,124	93,624	896	814	3.5	0
II	Scrub., Inc.	90,500	3,948	94,448	904	821	4.4	0.9
	ESP, Inc.	90,500	7,291	97,791	936	850	8.1	4.5
III	Scrub., Scrub.	90,500	3,848	94,348	903	820	4.3	0.8
	ESP, ESP	90,500	7,662	98,162	939	854	8.5	4.8
IV	Scrub., Scrub., Scrub.	90,500	4,028	94,528	905	822	4.5	1.0
	ESP, ESP, ESP	90,500	7,978	98,478	942	856	8.8	5.2
Model Plant No. 3								
I[d]	Scrub., Inc.	127,190	4,548	131,738	867	784	3.6	0
II	Scrub., Inc.	127,190	5,787	132,977	875	792	4.5	0.9
	ESP, Inc.	127,190	10,576	137,766	906	820	8.3	4.6
III	Scrub., Scrub.	127,190	5,891	133,081	876	792	4.6	1.0
	ESP, ESP	127,190	11,567	138,757	913	826	9.1	5.3
IV	Scrub., Scrub., Scrub.	127,190	6,177	133,367	877	794	4.9	1.2
	ESP, ESP, ESP	127,190	12,072	139,262	916	829	9.5	5.7

[a] Scrub. = venturi scrubber. Inc. = incinerator. ESP = wet electrostatic precipitator.

[b] January 1982 dollars.

[c] Normalized total is total capital cost divided by plant capacity.

[d] Baseline.

TABLE 8-10. BASIS FOR ESTIMATING CONTROL EQUIPMENT ANNUALIZED COSTS FOR NEW FACILITIES[8]
(January 1982 Dollars)

Cost element	Cost factor
Direct operating costs	
1. Utilities	
a. Electricity[2]	\$1.4 x 10^{-8}/J (\$0.0517/kWh)
b. Plant water[a]	\$0.18/1,000ℓ (\$0.68/1,000 gal)
c. Natural gas[b]	\$0.13/m^3 (\$3.76/1,000 ft^3)
2. Operating labor[c]	
a. Direct labor[5]	\$8.58/h (3 shifts/d; 333 d/yr) 1.25 h/shift: wet ESP, HVAF[d] 0.5 h/shift: incinerator 2.0 h/shift: 2,490 Pa (10-in.) scrubber 5.0 h/shift: 8,710 Pa (35-in.) scrubber
b. Supervision	15% of 2a
3. Maintenance[c]	
a. Labor	\$8.58/h (3 shifts/d; 333 d/yr) 0.75 h/shift: wet ESP, HVAF[d] 0.5 h/shift: incinerator 1.0 h/shift: 2,490 Pa (10-in.) scrubber 1.5 h/shift: 8,710 Pa (35-in.) scrubber
b. Material	100% of 3a
4. Solid waste transfer	\$33/Mg (\$30/ton)[b]
Indirect operating costs	
5. Overhead	80%(2a+2b+3a)
6. Capital charges	
a. Administrative	2% of capital cost
b. Property tax	1% of capital cost
c. Insurance	1% of capital cost
d. Capital recovery cost[e]	16.275% of capital cost
TOTAL ANNUALIZED COSTS (total of 1 through 6)	

[a] Based on costs in North Carolina.
[b] Estimate based on industry information.
[c] Per unit.
[d] Labor hours per unit for HVAF assumed equal to those for wet ESP.
[e] Based on 10 percent interest for 10-year life.

TABLE 8-11. ANNUALIZED COSTS OF MODEL FIBERGLASS LINES[a] 18,19

		Annualized costs					Percent increase in costs	
					Normalized total[d]			
Reg. Alt.	Control equipment[b]	Uncontrolled line, $000 per year[c]	Control equipment, $000 per year[c]	Total, $000 per year[c]	$ per yr per Mg	$ per yr per ton	Over uncontrolled	Over baseline
RS Small Line								
I[e]	Scrub., Inc.	15,791	768	16,559	920	828	4.9	0
II	Scrub., Inc.	15,791	1,120	16,911	940	846	7.1	2.1
	ESP, Inc.	15,791	1,152	16,943	941	847	7.3	2.3
III	Scrub., Scrub.	15,791	823	16,614	923	831	5.2	0.3
	ESP, ESP	15,791	833	16,624	924	831	5.3	0.4
IV	Scrub., Scrub., Scrub.	15,791	869	16,660	926	833	5.5	0.6
	ESP, ESP, ESP	15,791	864	16,655	925	833	5.5	0.6
RS Medium Line								
I[e]	Scrub., Inc.	30,004	793	30,797	906	810	2.6	0
II	Scrub., Inc.	30,004	1,179	31,183	917	821	3.9	1.3
	ESP, Inc.	30,004	1,205	31,209	918	821	4.0	1.3
III	Scrub., Scrub.	30,004	883	30,887	908	813	2.9	0.3
	ESP, ESP	30,004	888	30,892	909	813	3.0	0.3
IV	Scrub., Scrub., Scrub.	30,004	929	30,933	910	814	3.1	0.4
	ESP, ESP, ESP	30,004	929	30,933	910	814	3.1	0.4
RS Large Line								
I[e]	Scrub., Inc.	43,426	862	44,288	886	305	2.0	0
II	Scrub., Inc.	43,426	1,352	44,778	896	814	3.1	1.1
	ESP, Inc.	43,426	1,360	44,786	896	814	1.7	1.1
III	Scrub., Scrub.	43,426	1,057	44,483	890	809	2.4	0.4
	ESP, ESP	43,425	1,043	44,469	889	809	2.4	0.4
IV	Scrub., Scrub., Scrub.	43,425	1,103	44,529	891	810	2.5	0.5
	ESP, ESP, ESP	43,426	1,084	44,510	890	809	2.5	0.5
FA Small Line								
I[e]	None	4,684	0	4,684	1,041	937	0	0
II	HVAF	4,684	150	4,834	1,074	967	3.2	3.2
III	HVAF, HVAF	4,684	176	4,860	1,080	972	3.8	3.8
IV	HVAF	4,684	797	5,481	1,218	1,096	17.0	17.0

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[a] RS = rotary spin. FA = flame attenuation.
[b] Scrub. = venturi scrubber. Inc. = incinerator. ESP = wet electrostatic precipitator.
[c] January 1982 dollars.
[d] Normalized total is total annualized cost divided by line capacity.
[e] Baseline.

to 17.0 percent for an HVAF on forming on a small FA line (Regulatory Alternative IV). The overall percentage increase of annualized cost over the baseline is typically greatest for the RS small line and least for the RS medium and large lines.

8.1.1.4 Annualized Costs--Model Plants. Table 8-12 presents the annualized costs for the three RS model plants. The information is presented in the same format as that used for Table 8-11. The percentage of annualized cost increase over the baseline for the three model plants ranges from 0.3 percent for a wet ESP on forming and curing on model plant No. 1 (Regulatory Alternative III) to 2.0 percent for a wet ESP on forming and a low temperature incinerator on curing on model plant No. 1 (Regulatory Alternative II).

8.1.1.5 Cost Effectiveness. Tables 8-13 and 8-14 present a summary of the incremental annualized costs of pollution control with respect to both baseline and uncontrolled for the model lines. Table 8-15 presents a summary of the incremental annualized pollution control costs for the model RS plants.

Tables 8-16 and 8-17 summarize the emissions reduction of each regulatory alternative relative to both baseline and uncontrolled for the model lines. Table 8-18 summarizes the emission reduction of each regulatory alternative for the model RS plants.

Tables 8-19 and 8-20 present the average cost effectiveness of each regulatory alternative relative to baseline for the model RS and FA lines. Table 8-21 presents the average cost effectiveness values for the model RS plants. The average cost effectiveness over baseline is the incremental annualized cost of control per unit emission reduction over baseline in dollars per Mg (dollars per ton).

As shown in Table 8-19 for the RS lines, the average cost effectiveness values range from $205/Mg for a high pressure drop scrubber on forming and curing on a medium line (Regulatory Alternative III) to $2,010/Mg for a wet ESP on forming and a low temperature incinerator on curing on a small line (Regulatory Alternative II) ($185 to $1,830/ton). As shown in Table 8-20 for the FA line, the average cost effectiveness values range from $4,950/Mg for an HVAF on forming (Regulatory Alternative IV) to $16,450/Mg for an HVAF on curing and cooling (Regulatory Alternative III)

TABLE 8-12. ANNUALIZED COSTS OF MODEL FIBERGLASS PLANTS[18,19]

		Annualized costs					Percent increase in costs	
					Normalized total[c]			
Reg. Alt.	Control equipment[a]	Uncontrolled line, $000 per year[b]	Control equipment, $000 per year[b]	Total, $000 per year[b]	$ per yr per Mg	$ per yr per ton	Over uncontrolled	Over baseline
Model Plant No. 1								
I[d]	Scrub., Inc.	18,184	768	18,952	1,053	948	4.2	0
II	Scrub., Inc.	18,184	1,120	19,304	1,072	965	6.2	1.9
	ESP, Inc.	18,184	1,152	19,336	1,074	967	6.3	2.0
III	Scrub., Scrub.	18,184	823	19,007	1,056	950	4.5	0.3
	ESP, ESP	18,184	833	19,017	1,057	951	4.6	0.3
IV	Scrub., Scrub., Scrub.	18,184	869	19,053	1,059	953	4.3	0.5
	ESP, ESP, ESP	18,184	864	19,048	1,058	952	4.8	0.5
Model Plant No. 2								
I[d]	Scrub., Inc.	95,358	2,010	97,368	932	847	2.1	0
II	Scrub., Inc.	95,358	3,169	98,527	943	857	3.3	1.2
	ESP, Inc.	95,358	3,249	98,607	944	857	3.4	1.3
III	Scrub., Scrub.	95,358	2,488	97,846	936	851	2.6	0.5
	ESP, ESP	95,358	2,521	97,879	937	851	2.6	0.5
IV	Scrub., Scrub., Scrub.	95,358	2,603	97,961	937	852	2.7	0.6
	ESP, ESP, ESP	95,358	2,624	97,982	938	852	2.8	0.6
Model Plant No. 3								
I[d]	Scrub., Inc.	138,832	3,285	142,117	935	846	2.4	0
II	Scrub., Inc.	138,832	5,003	143,835	946	856	3.6	1.2
	ESP, Inc.	138,832	5,077	143,909	947	857	3.7	1.3
III	Scrub., Scrub.	138,832	3,304	142,636	938	849	2.7	0.4
	ESP, ESP	138,832	3,320	142,652	939	849	2.8	0.4
IV	Scrub., Scrub., Scrub.	138,832	4,004	142,836	940	850	2.9	0.5
	ESP, ESP, ESP	138,832	3,961	142,793	939	850	2.9	0.5

[a] Scrub. = venturi scrubber. Inc. = incinerator. ESP = wet electrostatic precipitator.

[b] January 1982 dollars.

[c] Normalized total is total annualized cost divided by plant capacity.

[d] Baseline.

TABLE 8-13. INCREMENTAL ANNUALIZED COSTS OF POLLUTION CONTROL SYSTEMS FOR MODEL FIBERGLASS LINES--ROTARY SPIN[18,19] ($000 per year)[a]

	Regulatory Alternative						
	I[b]	II		III		IV	
Control device[c]							
Forming	Scrub.	Scrub.	ESP	Scrub.	ESP	Scrub.	ESP
Curing	Inc.	Inc.	Inc.	Scrub.	ESP	Scrub.	ESP
Cooling	--	--	--	--	--	Scrub.	ESP
Line designation							
Small							
Incremental cost above:							
Baseline	0	352	384	55	65	101	96
Uncontrolled	768	1,120	1,152	823	833	869	864
Medium							
Incremental cost above:							
Baseline	0	386	412	90	95	136	136
Uncontrolled	793	1,179	1,205	883	888	929	929
Large							
Incremental cost above:							
Baseline	0	490	498	195	181	241	222
Uncontrolled	862	1,352	1,360	1,057	1,043	1,103	1,084

[a] January 1982 dollars.
[b] Baseline.
[c] Scrub. = venturi scrubber.
Inc. = incinerator.
ESP = wet electrostatic precipitator.
-- = uncontrolled.

TABLE 8-14. INCREMENTAL ANNUALIZED COSTS OF POLLUTION CONTROL SYSTEMS WITH RESPECT TO BASELINE FOR MODEL FIBERGLASS LINES--FLAME ATTENUATION[18]
($000 per year)[a]

	Regulatory alternative		
	II	III	IV
Control device[b]			
Forming	--	--	HVAF
Curing	HVAF	HVAF	--
Cooling	--	HVAF	--
Line designation			
Small Incremental cost above baseline (uncontrolled)	150	176	797

[a] January 1982 dollars.
[b] HVAF = high velocity air filter.
-- = uncontrolled.

TABLE 8-15. INCREMENTAL ANNUALIZED COSTS OF POLLUTION CONTROL SYSTEMS FOR MODEL FIBERGLASS PLANTS--ROTARY SPIN[18,19]
($000 per year)[a]

	Regulatory Alternative						
	I[b]	II		III		IV	
Control device[c]							
Forming	Scrub.	Scrub.	ESP	Scrub.	ESP	Scrub.	ESP
Curing	Inc.	Inc.	Inc.	Scrub.	ESP	Scrub.	ESP
Cooling	--	--	--	--	--	Scrub.	ESP
Model plant designation							
Small							
Incremental cost above:							
Baseline	0	352	384	55	65	101	96
Uncontrolled	768	1,120	1,152	823	833	869	864
Medium							
Incremental cost above:							
Baseline	0	1,159	1,239	478	511	593	614
Uncontrolled	2,010	3,169	3,249	2,488	2,521	2,603	2,624
Large							
Incremental cost above:							
Baseline	0	1,718	1,792	535	522	719	676
Uncontrolled	3,285	5,003	5,077	3,820	3,807	4,004	3,961

[a] January 1982 dollars.
[b] Baseline.
[c] Scrub. = venturi scrubber.
Inc. = incinerator.
ESP = wet electrostatic precipitator.
-- = uncontrolled.

TABLE 8-16. INCREMENTAL EMISSIONS REDUCTION OF MODEL FIBERGLASS LINES--ROTARY SPIN[18,19]

	Regulatory Alternative			
Line designation	I[a]	II	III	IV
Small				
Incremental reduction over:				
Baseline, Mg/yr	0	191	231	234
tons/yr	0	210	255	258
Uncontrolled, Mg/yr	239	429	470	473
tons/yr	263	473	518	521
Medium				
Incremental reduction over:				
Baseline, Mg/yr	0	362	440	445
tons/yr	0	399	485	490
Uncontrolled, Mg/yr	453	815	893	898
tons/yr	500	899	984	990
Large				
Incremental reduction over:				
Baseline, Mg/yr	0	524	636	644
tons/yr	0	578	701	710
Uncontrolled, Mg/yr	656	1,180	1,292	1,300
tons/yr	723	1,301	1,425	1,433

[a] Baseline.

TABLE 8-17. INCREMENTAL EMISSIONS REDUCTION OF MODEL FIBERGLASS LINES WITH RESPECT TO BASELINE--FLAME ATTENUATION[18]

Line designation	Regulatory alternative II	 III	 IV
Small			
Incremental reduction over baseline[a]			
Mg/yr	10	11	161
Tons/yr	11	12	178

[a]Baseline is uncontrolled.

TABLE 8-18. INCREMENTAL EMISSIONS REDUCTION OF MODEL FIBERGLASS PLANTS[18,19]

	Regulatory Alternative			
	I[a]	II	III	IV
1				
Incremental reduction over:				
Baseline, Mg/yr	0	191	231	234
tons/yr	0	210	255	258
Uncontrolled, Mg/yr	239	429	470	473
tons/yr	263	473	518	521
2				
Incremental reduction over:				
Baseline, Mg/yr	0	1,096	1,330	1,347
tons/yr	0	1,208	1,466	1,484
Uncontrolled, Mg/yr	1,372	2,467	2,701	2,718
tons/yr	1,512	2,720	2,979	2,996
3				
Incremental reduction over:				
Baseline, Mg/yr	0	1,601	1,943	1,967
tons/yr	0	1,764	2,142	2,167
Uncontrolled, Mg/yr	2,004	3,604	3,947	3,971
tons/yr	2,209	3,973	4,351	4,376

[a] Baseline.

TABLE 8-19. AVERAGE COST EFFECTIVENESS OF REGULATORY ALTERNATIVES WITH RESPECT TO BASELINE FOR MODEL FIBERGLASS LINES-- ROTARY SPIN[a] 18,19

	Regulatory Alternative					
	II		III		IV	
Control device[c]						
Forming Curing Cooling	Scrub. Inc. --	ESP Inc. --	Scrub. Scrub. --	ESP ESP --	Scrub. Scrub. Scrub.	ESP ESP ESP
Line designation						
Small						
$/Mg	1,845	2,010	240	280	430	410
$/ton	1,675	1,830	215	255	390	370
Medium						
$/Mg	1,065	1,140	205	215	305	305
$/ton	965	1,035	185	195	275	275
Large						
$/Mg	1,935	950	305	285	375	345
$/ton	850	860	280	260	340	315

[a] January 1982 dollars.

[b] Scrub. = venturi scrubber.
Inc. = incinerator.
ESP = wet electrostatic precipitator.
-- = uncontrolled.

TABLE 8-20. AVERAGE COST EFFECTIVENESS OF REGULATORY ALTERNATIVES WITH RESPECT TO BASELINE FOR MODEL FIBERGLASS LINES--FLAME ATTENUATION[a] 18

	Regulatory alternative		
	II	III	IV
Control device[b]			
Forming	--	--	HVAF
Curing	HVAF	HVAF	--
Cooling	--	HVAF	--
Line designation			
Small, $/Mg	15,790	16,450	4,950
$/ton	14,285	14,980	4,490

[a] January 1982 dolllars.

[b] HVAF = high velocity air filter.

-- = uncontrolled.

TABLE 8-21. AVERAGE COST EFFECTIVENESS OF REGULATORY ALTERNATIVES WITH RESPECT TO BASELINE FOR MODEL FIBERGLASS PLANTS--ROTARY SPIN[a] [18,19]

	Regulatory Alternative					
	II		III		IV	
Control device[b]						
Forming	Scrub.	ESP	Scrub.	ESP	Scrub.	ESP
Curing	Inc.	Inc.	Scrub.	ESP	Scrub.	ESP
Cooling	--	--	--	--	Scrub.	ESP
Model plant designation						
1						
$/Mg	1,845	2,010	240	280	430	410
$/ton	1,675	1,830	215	255	390	370
2						
$/Mg	1,055	1,130	360	380	440	455
$/ton	960	1,025	325	345	400	415
3						
$/Mg	1,075	1,120	275	270	365	345
$/ton	975	1,015	250	245	330	310

[a] January 1982 dollars.

[b] Scrub. = venturi scrubber.
Inc. = incinerator.
ESP = wet electrostatic precipitator.
-- = uncontrolled.

($4,490 to $14,980/ton). Of the RS lines, the small line has the highest overall cost effectiveness values while the medium line has the lowest overall cost effectiveness values.

Tables 8-22 and 8-23 present the average cost effectiveness of each regulatory alternative relative to uncontrolled for the model RS lines and model plants. As shown in Table 8-22 for the RS lines, the average cost effectiveness values range from $805/Mg for a wet ESP on forming and curing on a large line (Regulatory Alternative III) to $3,215/Mg for a low pressure drop scrubber on forming and a low temperature incinerator on curing on a small line (Regulatory Alternative I) ($730 to $2,920/ton).

8.1.2 Modified/Reconstructed Facilities

Under the provisions of 40 CFR 60.14 and 60.15, an "existing facility" may become subject to standards of performance if it is deemed modified or reconstructed. In such situations control devices may have to be installed for compliance with new source performance standards.

The cost for installing a control system on an existing facility may be greater than the cost of installing the control system on a new facility. Since retrofit costs are highly site-specific they are difficult to estimate. The availability of space and the configuration of existing equipment in the plant are the major limiting site-specific factors. Because capture hoods used in this industry are considered a part of the process equipment, the primary increase in cost of installing a control system on an existing facility would result from any increased structural support necessary for the added ductwork. No significant increase in control device capital or annualized costs would be expected for a modified or reconstructed source.

8.2 OTHER COST CONSIDERATIONS

In addition to costs associated with the Clean Air Act, the wool fiberglass manufacturing industry may also incur costs as a result of other Federal rules or regulations. These impacts are discussed in this section.

TABLE 8-22. AVERAGE COST EFFECTIVENESS OF REGULATORY ALTERNATIVES WITH RESPECT TO UNCONTROLLED FOR MODEL FIBERGLASS LINES--ROTARY SPIN[a] [18,19]

	Regulatory Alternative						
	I[b]	II		III		IV	
Control device[c]							
Forming	Scrub.	Scrub.	ESP	Scrub.	ESP	Scrub.	ESP
Curing	Inc.	Inc.	Inc.	Scrub.	ESP	Scrub.	ESP
Cooling	--	--	--	--	--	Scrub.	ESP
Line designation							
Small							
$/Mg	3,215	2,610	2,685	1,750	1,770	1,835	1,825
$/ton	2,920	2,370	2,435	1,590	1,610	1,670	1,660
Medium							
$/Mg	1,750	1,445	1,480	990	995	1,035	1,035
$/ton	1,585	1,310	1,340	895	900	940	940
Large							
$/Mg	1,315	1,145	1,155	820	805	850	835
$/ton	1,190	1,040	1,045	740	730	770	755

[a] January 1982 dollars.
[b] Baseline.
[c] Scrub. = venturi scrubber.
Inc. = incinerator.
ESP = wet electrostatic precipitator.
-- = uncontrolled.

TABLE 8-23. AVERAGE COST EFFECTIVENESS OF REGULATORY ALTERNATIVES WITH RESPECT TO UNCONTROLLED FOR MODEL FIBERGLASS PLANTS--ROTARY SPIN[a] [18,19]

	Regulatory Alternative						
	I[b]	II		III		IV	
Control device[c]							
Forming	Scrub.	Scrub.	ESP	Scrub.	ESP	Scrub.	ESP
Curing	Inc.	Inc.	Inc.	Scrub.	ESP	Scrub.	ESP
Cooling	--	--	--	--	--	Scrub.	ESP
Model plant designation							
1							
$/Mg	3,215	2,610	2,685	1,750	1,770	1,835	1,825
$/ton	2,920	2,370	2,435	1,590	1,610	1,670	1,660
2							
$/Mg	1,465	1,285	1,315	920	930	960	965
$/ton	1,330	1,165	1,195	835	845	870	875
3							
$/Mg	1,640	1,390	1,410	970	965	1,010	995
$/ton	1,485	1,260	1,280	880	875	915	905

[a] January 1982 dollars.
[b] Baseline.
[c] Scrub. = venturi scrubber.
Inc. = incinerator.
ESP = wet electrostatic precipitator.
-- = uncontrolled.

8.2.1 Water Pollution Control Act

The wool fiberglass manufacturing industry is included in the glass manufacturing point source category for which effluent guideline limitations have been promulgated (40 CFR 426).[20] The standards of performance for new sources specify zero discharge of process wastewater to navigable waters. The wool fiberglass industry currently practices total water recycle of process water; the water is reused in binder formulation, duct sprays, forming section sprays, or control device sprays.

Several of the control devices (wet ESP's, scrubbers) require the use of water and result in an increase in wastewater volume. The cost of treating this water (i.e., screening and settling) to a level suitable for recycle has been included in the cost analyses.

8.2.2 Resource Conservation and Recovery Act

Waste generated by the manufacture of wool fiberglass insulation or by air pollution control devices associated with its manufacture is not currently classified as hazardous or toxic under the provisions of the Resource Conservation and Recovery Act (RCRA). However, classification of the wastes by the various State and local agencies varies widely, ranging from nonhazardous to hazardous. A cost for solid waste disposal of $30/ton for landfilling has been included in the cost analyses.

8.2.3 Occupational Safety and Health Administration Act

No data were obtained regarding the cost to the industry of compliance with the Occupational Safety and Health Administration Act (OSHA). The control equipment used in evaluating the impacts of the regulatory alternatives should result in minimal OSHA-related compliance costs. The industry's ability to comply with any one of the regulatory alternatives would, therefore, not be greatly affected by the economic impact of OSHA regulations.

8.2.4 Resource Requirements Imposed on State, Regional, and Local Agencies

The owner or operator of a wool fiberglass insulation facility is responsible for making application to the State for a permit to construct and subsequently operate a new installation. The review of these applications, and any later enforcement action, would be handled by local, State, or regional regulatory agencies. Since it is projected that 30 line additions and 5 plants will become affected facilities through

1991, that these lines and plants will be distributed through the United States instead of clustered in one State, and that they will be added in States already having wool fiberglass insulation facilities, the promulgation of standards for wool fiberglass insulation manufacturing facilities should not impose major resource requirements on the regulatory agencies.

8.3 REFERENCES FOR CHAPTER 8

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9. ECONOMIC ANALYSIS

9.1 INDUSTRY PROFILE

9.1.1 Introduction

The wool fiberglass insulation industry is covered under the Standard Industrial Classification (SIC) Code 3296, Mineral Wool.[1] The fiberglass category includes that part of the mineral wool classification in which molten glass is fiberized and chemically bonded with an organic material (binder) into a wool-like insulating material. Wool fiberglass currently comprises about 63 percent of SIC 3296.[2-4] Textile fiberglass (SIC Code 3229) is not included in this fiberglass source category.

Wool fiberglass can be used for structural or nonstructural purposes. Structural uses include the thermal insulation of new residential and nonresidential structures as well as the retrofitting of insulation to existing structures. Nonstructural uses are diverse and include pipe insulation, appliance and other equipment insulation, automotive insulation, acoustical ceiling insulation, and rigid fiberglass ductboard in air-handling equipment.[5] In 1981, about 81 percent of the wool fiberglass produced was used for the insulation of new and existing structures. The remaining 19 percent was used in nonstructural applications.[2] Fiberglass is usually sold in the form of batts and blankets (with or without a vapor barrier) or is shredded, lubricated, and packaged as blowing wool.

Wool fiberglass is currently produced by five firms in the United States, and there are 25 plants in 11 States.[6-12] Three of the firms had 99 percent of total U.S. capacity in 1980.[13] The industry is oligopolistic in structure, and Owens-Corning Fiberglas is the acknowledged price leader.[13]

9.1.2 Firm Characteristics

9.1.2.1 Ownership. The five firms that produce all of the wool fiberglass in the United States are CertainTeed Corporation (CT), Guardian

Industries Inc., Knauf Fiber Glass GmbH, Manville Corporation, and Owens-Corning Fiberglas Corporation (OCF). With the exception of Knauf, the firms are publicly held. (A diversified French industrial group, St. Gobain Pont Mousson, owns 54 percent of CertainTeed.)[14]

9.1.2.2 Geographic Location. Table 9-1 lists plant locations by firm. Figure 9-1 shows that most of the plants are located in the Eastern half of the United States. Five plants are located in the Central States, and four in California.

There are several reasons for this geographic choice of plant location. One reason is that both the glass raw materials and the finished products are bulky, so plants tend to be located near sources of supply or demand. Other factors in plant siting include fuel availability (because the process is energy-intensive) and State and local environmental regulations.[15-17]

9.1.2.3 Concentration. The industry was a monopoly from 1938 to 1949 when OCF held exclusive process patents in glass fiber production. In 1949, OCF signed a consent decree permitting other firms to receive patent licenses.[18]

Four other firms have since entered the industry, but OCF remains the dominant firm. Table 9-2 lists the estimated capacity of each of the four firms that produced wool fiberglass throughout 1979 and 1980. (Guardian Industries' plant started up in late 1980.)[19] In 1980, OCF had 63 percent of total industry capacity, and OCF is currently said to be the only producer of wool fiberglass nonresidential roof insulation.[20] CertainTeed and Manville split most of the remaining capacity, with CT having 20.3 percent of total industry capacity and Manville having 15.6 percent of capacity. Knauf had an estimated 1.1 percent of capacity. The new plant by Guardian Industries is estimated to have added only slightly to industry capacity.

9.1.2.4 Vertical and Horizontal Integration. The three major firms in the wool fiberglass industry are both vertically and horizontally integrated. No information is currently available about Guardian Industries or Knauf.

There is both backward and forward vertical integration in the three major firms. Backward vertical integration occurs when a firm supplies

TABLE 9-1. LOCATION OF INSULATION FIBERGLASS PLANTS IN THE UNITED STATES 6-12

Company/headquarters address	Plants
CertainTeed Corporation Valley Forge, Pa. 19482	Athens, Ga. Chowchilla, Calif. Kansas City, Kans. Berlin, N.J. Mountain Top, Pa.
Guardian Industries, Inc. 43043 W. Nine Mile Road Northville, Mich. 48167	Albion, Mich.
Knauf Fiber Glass GmbH 240 Elizabeth Street Shelbyville, Ind. 46176	Shelbyville, Ind.
Manville Corporation Ken-Caryl Ranch Denver, Colo. 80217	Corona, Calif. Willows, Calif. Winder, Ga. Richmond, Ind. McPherson, Kans. Berlin, N.J. Defiance, Ohio (3 plants) Cleburne, Tex. Parkersburg, W. Va.
Owens-Corning Fiberglas Corporation Fiberglas Tower Toledo, Ohio 43659	Santa Clara, Calif. Fairburn, Ga. Kansas City, Kans. Barrington, N.J. Delmar, N.Y. Newark, Ohio Waxahachie, Tex.

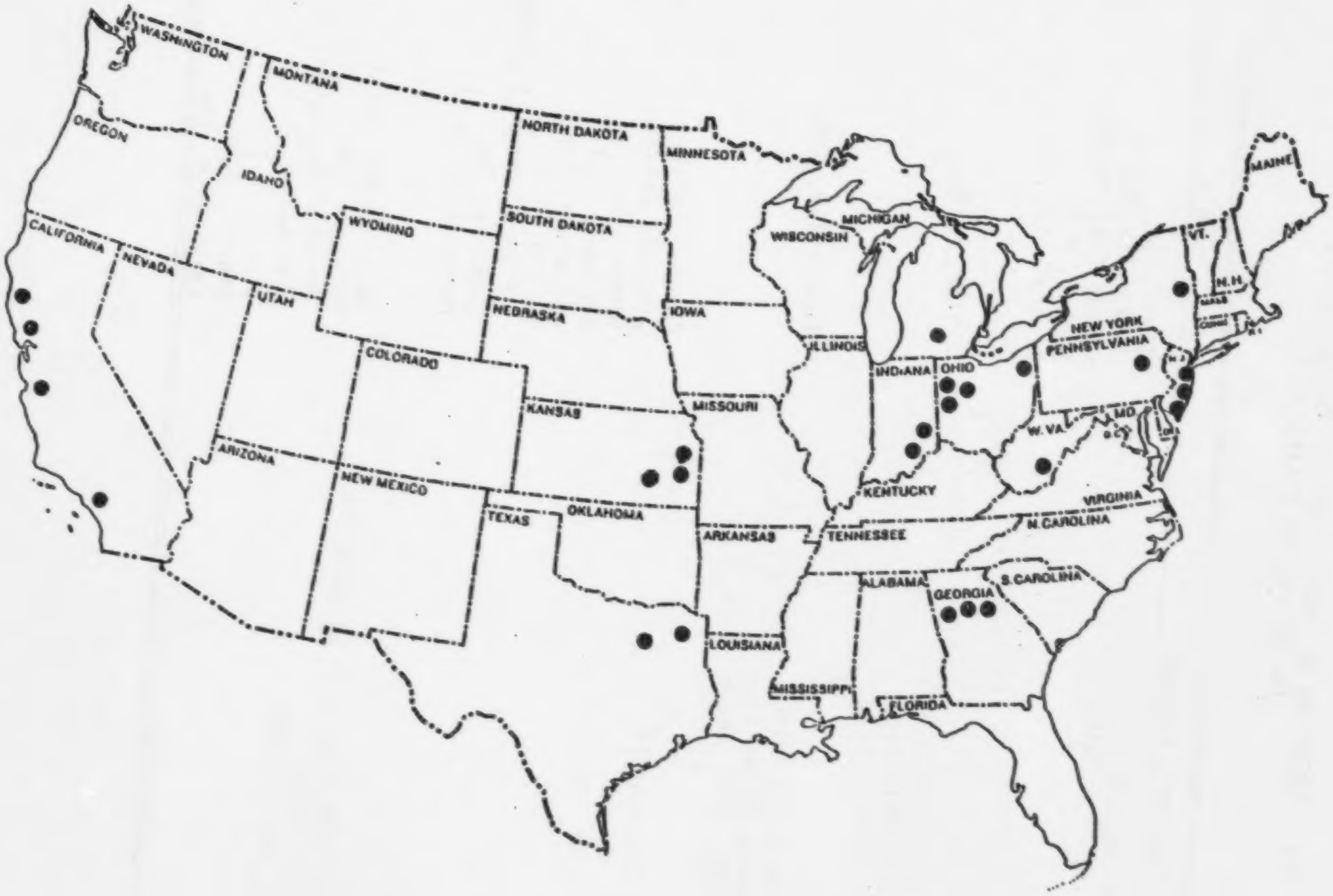
WASHINGTON
MONTANA
OREGON
IDAHO
NORTH DAKOTA
MINNESOTA
MAINE
SOUTH DAKOTA
WYOMING
MICHIGAN
WISCONSIN
VT.
N.H.
CALIFORNIA
NEVADA
UTAH
NEBRASKA
IOWA
NEW YORK
PENNSYLVANIA
ILLINOIS
INDIANA
OHIO
COLORADO
KANSAS
MISSOURI
W. VA.
MD
ARIZONA
NEW MEXICO
KENTUCKY
VIRGINIA
TEXAS
OKLAHOMA
ARKANSAS
TENNESSEE
N. CAROLINA
ALABAMA
GEORGIA
S. CAROLINA
LOUISIANA
MISSISSIPPI
FLORIDA

Figure 9-1. Location of wool fiberglass plants in the United States.

TABLE 9-2. ESTIMATED CAPACITY, BY FIRM, IN 1979 AND 1980[13,21]

Year	CertainTeed			Knauf			Manville			Owens-Corning			Industry Total		
	Capacity (Gg)	Capacity 10^6 lb	Share (%)	Capacity (Gg)	Capacity 10^6 lb	Share (%)	Capacity (Gg)	Capacity 10^6 lb	Share (%)	Capacity (Gg)	Capacity 10^6 lb	Share (%)	Capacity (Gg)	Capacity 10^6 lb	Share (%)
1979	286	630	18.4	18	40	1.2	245	540	15.8	1,003	2,210	64.6	1,552	3,420	100.0
1980	331	730	20.3	18	40	1.1	254	560	15.6	1,028	2,265	63.0	1,631	3,595	100.0

its own materials rather than purchasing raw materials on the open market. Owens-Corning, CT, and Manville all supply their own sand, which is a major raw material.[22] Forward vertical integration occurs when a firm has its own retail distribution center. Wool fiberglass producers have captive distribution centers that enable them to market products nationwide. CertainTeed, for example, distributes insulation products through the Cameron Wholesale operation.[6]

Horizontal integration occurs when a firm produces more than one type of product. CertainTeed and Manville are broad-based companies serving the construction materials industry.[6-12] CertainTeed, Manville, and Owens-Corning produce both wool fiberglass (part of SIC 3296) and also textile fiberglass (SIC 3229). Wool fiberglass is used for thermal insulation, and textile fiberglass is used in plastic reinforcements and yarns.[23]

9.1.2.5 Entry. Entry into the industry by new firms is inhibited by the dominant position of the three major manufacturers who have well established marketing networks, the size of the entry investment in plant and equipment ($25 million per plant), and the limited availability of technical and process information to those outside the industry.[24] Despite this, Guardian Industries entered the market in late 1980 by purchasing a flat glass plant from Corning Glass and converting it to produce wool fiberglass insulation.[25]

Knauf, on the other hand, entered the market in the late-1970's by purchasing a plant in Indiana from CT. The plant was available only because CT was ordered to divest itself of the facility by the courts.[26]

9.1.3 Industry Characteristics

9.1.3.1 Historical Shipments and Prices in the Total Wool Fiberglass Market. Shipments and price trends in wool fiberglass are summarized in Table 9-3. The quantity of shipments of wool fiberglass increased from 475 gigagrams (Gg) (1,046 x 10^6 pounds (lb)) in 1965 to 1,112 Gg (2,449 x 10^6 lb) in 1981, or at an annual compound growth rate of 5.5 percent. Growth in shipments was more rapid (6.8 percent) in the Seventies. Output is cyclical, with downturns occurring in the recessions of 1970, 1975, and 1980-1981.

The value of shipments increased more rapidly than the quantity of shipments between 1965 and 1981. The annual compound growth rate in this

TABLE 9-3. SHIPMENTS AND PRICE OF WOOL FIBERGLASS, 1965 TO 1981[2, 27-29]

		Shipments		Value of shipments		Price[a]			Price index of wool fiberglass		Price index of cost of construction		Ratio of the price index of wool fiberglass to the index of the total cost of construction	
Year	Gg	10^6 lb	% change	\$ 10^6	% change	Avg. \$/lb	\$/kg	% change	1967 = 100	% change	1967 = 100	% change	1967 = 100	% change
1965	475	1,045.7	--	250.5	--	0.239	0.526	--	89.2		92.8		96.1	
1966	488	1,075.6	2.9	282.1	12.6	0.262	0.578	9.9	97.4	9.2	96.4	3.9	101.0	5.1
1967	471	1,037.5	-3.5	279.3	-1.0	0.269	0.593	2.6	100.0	2.7	100.0	3.7	100.0	- 1.0
1968	510	1,124.3	8.4	312.0	11.7	0.278	0.613	3.4	103.3	3.3	105.1	5.1	98.3	- 1.7
1969	546	1,202.7	7.0	355.2	13.8	0.295	0.650	6.0	109.7	6.2	114.2	8.7	96.1	- 2.2
1970	539	1,186.3	-1.4	355.8	0.2	0.300	0.662	1.8	111.5	1.6	122.4	7.2	91.1	- 5.2
1971	689	1,517.2	27.9	425.3	19.5	0.280	0.617	-6.8	104.1	-6.6	130.9	6.9	79.5	-12.7
1972	800	1,761.9	16.1	488.3	14.8	0.277	0.611	-1.0	103.0	-1.1	138.1	5.5	74.6	- 6.2
1973	880	1,939.0	10.1	560.5	14.8	0.289	0.637	4.3	107.4	4.3	150.1	8.7	71.6	- 4.0
1974	893	1,967.5	1.5	647.6	15.5	0.329	0.725	13.8	122.3	13.9	175.3	16.8	70.0	- 2.2
1975	777	1,711.9	-13.0	689.1	6.4	0.403	0.889	22.6	149.8	22.5	191.2	9.1	78.3	11.9
1976	942	2,074.0	21.2	859.6	24.7	0.414	0.913	2.7	153.9	2.7	198.8	4.0	77.4	- 1.1
1977	1,165	2,565.7	23.7	1,108.0	28.9	0.432	0.953	4.4	160.6	4.4	216.2	8.8	74.3	- 4.0
1978	1,232	2,714.4	5.8	1,265.9	14.3	0.466	1.028	7.9	173.2	7.8	244.3	13.0	70.9	- 4.6
1979	1,296	2,854.8	5.2	1,368.2	8.1	0.479	1.056	2.7	178.1	2.8	278.5	14.0	63.9	- 9.9
1980	1,190	2,622.1	-8.2	1,422.1	3.9	0.542	1.195	13.2	201.5	13.2	309.7	11.2	65.1	1.9
1981	1,112	2,449.4	-6.6	1,482.6	4.3	0.605	1.333	11.6	224.9	11.6	329.8	6.5	68.2	4.0
Annual compound growth rates[b]														
1965 to 1981		5.5	--	11.8	--	6.0		--		--		--		--
1970 to 1981		6.8	--	13.9	--	6.6		--		--		--		--
1975 to 1981		6.2	--	13.6	--	7.0		--		--		--		--

[a] Price is the average value per pound of shipments. It is the value of shipments divided by the quantity of shipments.

[b] Compound growth rates are calculated using two equations: (1) $G = (X_n/X_1)^{1/n}$
where G = compound growth multiplier; X_n = the value of X in the time period
n; X_1 = the value of X in time period 1; n = the length of time period; and
(2) The compound growth rate (C) can be found by: $C = G - 1$.

period was 11.8 percent, and there was no decline in the value of output during recessions.

Wholesale prices (average value of shipments per unit weight) rose from \$0.526 per kilogram (kg) (\$0.239 per lb) in 1965 to \$1.333 per kg (\$0.605 per lb) in 1981, or at an annual compound rate of 6.0 percent per year. Prices declined in 1971 and 1972, but these declines were unrelated to a business cycle.

The real price of wool fiberglass (the price index of wool fiberglass divided by the index of the cost of construction) has fallen in most years since 1965; 1975, 1980, and 1981 are exceptions.

9.1.3.2 Historical Shipments and Prices in Structural Versus Nonstructural Markets. As noted earlier, wool fiberglass can be used for structural or nonstructural purposes. Estimates of the end-uses of wool fiberglass in 1980 and their shares of the total are presented in Table 9-4.

Table 9-5 tracks the historical behavior of shipments and prices of structural versus nonstructural insulation between 1965 and 1981. Information on the share of total shipments and value of shipments used for structural uses relative to total usage of wool fiberglass are also given.

From this table, one can see that the behavior of output in the two markets has differed rather dramatically. The structural market, on the one hand, has been a growth sector. Shipments grew at an annual compound rate of 9.9 percent between 1965 and 1981. In addition, they rose in every year except three of the recession years, 1974, 1980, and 1981. Nonstructural shipments, on the other hand, declined at an annual compound growth rate of 1.5 percent between 1965 and 1981. (In recent years, nonstructural usage has risen from an historical low of 180 Gg (396.4 x 10^6 lb) in 1975 to 215 Gg (474.2 x 10^6 lb) in 1981.) As a result of these divergent trends, the share of output of structural insulation has grown from about 42 percent of the total market in 1965 to a current high of about 81 percent.

The historical trends in the value of shipments do not show the previous patterns as dramatically as the trends in physical output because the price of nonstructural insulation has been higher and has also

TABLE 9-4. ESTIMATES OF THE DEMAND FOR WOOL FIBERGLASS IN 1980 BY END-USE[30]

End-Use	Demand		Share (percent of total demand)
	Gg	10^6 lb	
Structural			
Residential			
New houses	321	706	27.2
Mobile homes	54	120	4.6
Retrofit of existing houses	361	795	30.6
Total residential	736	1,621	62.4
Nonresidential[a]	197	435	16.8
Total structural	933	2,056	79.2
Nonstructural			
Pipe insulation	79	175	6.7
Air handling	59	130	5.0
Other	107	235	9.1
Total nonstructural	245	540	20.8
Total[b]	1,178	2,596	100.0

[a] Includes nonresidential use of light-density and heavy-density (roof) insulation.

[b] The total of 2,596 x 10^6 lb is based on preliminary estimates of industry output in 1980 by Census.

TABLE 9-5. SHIPMENTS AND PRICE OF STRUCTURAL VERSUS NONSTRUCTURAL USE OF WOOL FIBERGLASS, 1965 TO 1981[2,27,31-35]

Year	Structural[a]					Nonstructural[a]					Share of structural in total	
	Shipments		Value of shipments	Price[b]		Shipments		Value of shipments	Price[b]		Ship-ments[c]	Value of shipments[d]
	(Gg)	(10⁶ lb)	\$ 10⁶	(\$/kg)	(\$/lb)	(Gg)	(10⁶ lb)	\$ 10⁶	(\$/kg)	(\$/lb)	(%)	(%)
1965	197	437.6	92.5	0.465	0.211	276	608.1	157.9	0.573	0.260	41.6	36.9
1966	210	462.4	104.8	0.501	0.227	278	613.2	177.3	0.637	0.289	43.0	37.1
1967	220	483.6	108.8	0.496	0.225	252	554.0	170.5	0.679	0.308	46.6	39.0
1968	258	567.3	133.0	0.516	0.234	253	557.0	178.9	0.708	0.321	50.5	37.4
1969	285	627.5	157.6	0.553	0.251	261	575.2	197.6	0.759	0.344	52.2	44.3
1970	293	644.8	165.6	0.567	0.257	246	541.5	190.2	0.774	0.351	54.4	46.5
1971	404	890.2	218.2	0.540	0.245	285	627.0	207.0	0.728	0.330	58.6	51.3
1972	479	1,054.8	267.7	0.560	0.254	321	707.1	220.6	0.688	0.312	59.9	54.8
1973	541	1,191.5	312.6	0.578	0.262	339	747.5	247.9	0.732	0.332	61.5	55.8
1974	531	1,169.5	342.9	0.646	0.293	362	798.0	304.7	0.842	0.382	59.5	52.9
1975	597	1,315.5	440.6	0.739	0.335	180	396.4	248.5	1.383	0.627	76.8	63.9
1976	751	1,654.6	564.7	0.752	0.341	190	419.4	294.9	1.550	0.703	79.8	65.7
1977	947	2,086.7	761.9	0.805	0.365	220	483.9	356.7	1.625	0.737	81.1	68.8
1978	1,011	2,227.5	872.3	0.864	0.392	221	486.8	393.7	1.784	0.809	82.1	68.9
1979	1,064	2,343.7	930.4	0.875	0.397	232	511.1	437.8	1.890	0.857	82.1	68.0
1980	969	2,143.3	968.7	1.000	0.454	221	487.8	453.4	2.050	0.930	81.4	68.1
1981	897	1,975.2	1,012.8	1.128	0.512	215	474.2	469.8	2.184	0.991	80.6	68.3
Annual compound growth rates												
1965 to 1981		9.9	16.1		5.7		- 1.5	7.1		8.7	4.2	3.9
1970 to 1981		10.7	17.9		6.5		- 1.2	8.6		9.9	3.6	3.6
1975 to 1981		7.0	14.9		7.3		3.0	11.2		7.9	0.8	1.1

[a] Data for 1965 to 1974 may not be comparable to data beginning in 1975 because of misclassifications between structural and nonstructural in years prior to 1975.

[b] Price is the average value per pound of shipments. It is the value of shipments divided by the quantity of shipments.

[c] Quantity of shipments of structural wool fiberglass insulation divided by total quantity of shipments of wool fiberglass insulation in Table 9-3.

[d] Value of shipments of structural wool fiberglass insulation divided by total value of shipments of wool fiberglass insulation in Table 9-3.

grown at a more rapid rate than the price of structural insulation. As a result, the share of structural insulation measured by value of output has grown from about 37 percent in 1965 to a high of 68 percent in recent years.

The price of nonstructural insulation is higher than the price of structural insulation because nonstructural insulation is a heavy density product. Heavy-density insulation provides more insulating value per unit of thickness than does the light-density material, but heavy density costs more to produce. Hence, it sells at a higher price per unit weight than light density wool fiberglass.[36]

9.1.3.3 Employment. Table 9-6 contains data on the estimated employment of production workers and all workers from 1965 to 1979, as well as the base for these estimates. Total employment in the wool fiberglass industry in 1979 was 15,100, with 12,300 employees being production workers and the remaining 2,800 being nonproduction workers.

9.1.3.4 International Trade. Data on the value of imports and exports are presented in Table 9-7. The value of imports sharply increased during 1977 and 1978 and then declined in 1979. During these two years, housing starts increased and there was a vast increase in retrofitting. Since the industry could not meet the demand, the United States had to import wool fiberglass. By 1979 the industry had increased capacity. Overcapacity occurred in 1979 because housing starts decreased in 1979 and the retrofit market was 1 million units less than its 1977 historical high point.

Canada, Germany, and Mexico are the major suppliers of wool fiberglass to the United States. Canada is also the major market for U.S. exports.[37]

Overall, the imports and exports are not important factors in this industry. Imported fiberglass accounted for less than 1 percent of total fiberglass sales, and exported fiberglass accounted for approximately 2 percent of total fiberglass sales in 1979. In the future, imports and exports are expected to continue to be an insignificant portion of the wool fiberglass industry.[37]

9.1.3.5 Substitutes. Wool fiberglass competes with rock wool, cellulose, and polystyrene foam in the structural insulation market. The principal residential applications of insulation materials are shown in Table 9-8. In 1976 the structural insulation market was divided as

TABLE 9-6. ESTIMATED EMPLOYMENT IN WOOL FIBERGLASS, 1965 TO 1979[2-4]

Year	Share of wool fiberglass in SIC 3296[a]	Total mineral wool (SIC 3296)		Total wool fiberglass	
		Number of production workers (10^3)	Total number of employees (10^3)	Number of production workers (10^3)[b]	Total number of employees (10^3)[c]
1965	0.582	12.2	15.4	7.10	8.96
1966	0.612	12.9	16.1	7.89	9.85
1967	0.615	12.2	15.1	7.50	9.29
1968	0.641	11.7	14.5	7.50	9.29
1969	0.658	12.4	15.3	8.16	10.1
1970	0.636	12.8	15.8	8.14	10.0
1971	0.664	13.1	16.2	8.70	10.8
1972	0.646	14.7	18.0	9.50	11.6
1973	0.645	15.5	18.7	10.00	12.1
1974	0.611	16.0	19.5	9.78	11.9
1975	0.602	14.5	18.1	8.73	10.9
1976	0.619	16.6	20.3	10.28	12.6
1977	0.619	18.6	22.6	11.51	14.0
1978	0.627	19.7	24.1	12.35	15.1
1979	0.628	19.6	24.1	12.31	15.1
Annual compound growth rates					
1965 to 1979	--	--	--	4.0	3.8
1970 to 1979	--	--	--	4.7	4.7
1975 to 1979	--	--	--	9.0	8.5

[a] Value of shipments in wool fiberglass divided by the value of shipments in mineral wool (SIC 3296).

[b] The share of wool fiberglass times the number of production workers in mineral wool (SIC 3296).

[c] The share of wool fiberglass times the total number of employees in mineral wool (SIC 3296).

TABLE 9-7. VALUE OF IMPORTS AND EXPORTS ($000)[38, 39]

Year	Imports[a]	Exports[b]
1975	413	NA[c]
1976	1,398	23,599
1977	NA	23,688
1978	7,048	21,804
1979	3,027	25,480
1980	NA	24,061[d]

[a] Imports classification: Mineral wool includes bulk, batts, blanket, etc.
[b] Exports classification: Glass fiber articles for insulation.
[c] NA = not available.
[d] January to September 1980 only.

TABLE 9-8. PRINCIPAL RESIDENTIAL INSULATION APPLICATIONS[40]

Locations	Fiberglass	Rock wool	Cellulose	Cellular plastics	Vermiculite	Reflective surfaces
New construction						
Roof/ceiling	X	X	X	X		
Walls	X	X		X		X
Floors/foundation	X	X		X		X
Retrofit						
Roof/ceiling	X	X	X	X	X	
Walls	X	X	X	X		
Floors/foundation	X	X		X		X

follows: wool fiberglass--62 percent; rock wool--20 percent; cellulose--14 percent; formaldeyde foam--1.1 percent; and polystyrene--2.9 percent. Since 1976, wool fiberglass, cellulose, formaldehyde foam, and polystyrene have increased their market shares slightly.[41] Although foam and mineral wool insulation possess desirable properties, their cost per R-value (insulating ability) is generally higher than that of fiberglass. In addition, cellulose and foam have the disadvantage of being flammable materials. Formaldehyde foam has also recently been linked to health problems. According to the U.S. Consumer Products Safety Commission, formaldehyde foam can no longer be manufactured after August 10, 1982. It is likely that fiberglass will continue to increase its substantial share of the structural insulation market because of its low cost, light weight, low thermal conductivity, and fire resistance.[24]

Fiberglass maintains only a small share of the nonstructural insulation market (appliance, pipe, and industrial) because of effective competition from materials such as wood fiberboard, tectum, gypsum, perlite board, polyurethane, and ceramic insulation materials. In pipe insulation, for example, polyurethane has become the dominant insulating material.[42]

9.1.3.6 Demand Determinants. The demand for wool fiberglass is largely determined by five variables: (1) the price of wool fiberglass relative to the total cost of construction; (2) economic activity in the industries that use wool fiberglass as an insulation material; (3) the price of all types of insulation relative to the price of energy, a factor which in turn explains the total amount of insulation installed per unit of output in the user industries; (4) the price of wool fiberglass relative to the prices of its close substitutes, a variable which largely explains the percent of wool fiberglass installed relative to the total amount of insulation installed; and (5) in recent years, the existence of the income tax credit for the insulation (or reinsulation) of existing residential structures.

Table 9-9 summarizes historical data from 1965 to 1980 for three of the determinants as well as the values assumed for a time trend proxy employed for the two remaining determinants. The proxy variable is included to capture monotonic and systematic changes in these two determinants. For example, the time trend captures the increasing amount of

TABLE 9-9. DETERMINANTS OF THE DEMAND FOR WOOL FIBERGLASS, 1965 TO 1980[30, 43, 44]

Year	Ratio of the price index of wool fiberglass to the index of the total cost of construction		Economic activity in the user industry										Tax credit for insulating existing residences	Time trend[a]
			Housing starts		Mobile homes		Nonresidential construction		Total new construction		Retrofit market			
	1967 = 100	% change	10^6 units	% change	10^6 units	% change	10^9 1977 $	% change	10^9 1977 $	% change	10^6 units	% change		
1965	96.1		1.510		0.216		107.2		170.0		0.5		0.0	4
1966	101.0	5.1	1.196	-20.8	0.217	0.5	113.5	5.9	169.1	- 0.5	0.5	0.0	0.0	5
1967	100.0	- 1.0	1.322	10.5	0.240	10.6	113.1	- 0.4	166.7	- 1.4	0.5	0.0	0.0	6
1968	98.3	- 1.7	1.545	16.9	0.318	32.5	115.8	2.4	176.2	5.7	0.5	0.0	0.0	7
1969	96.1	- 2.2	1.500	- 2.9	0.413	29.9	115.3	- 0.4	176.6	0.2	0.5	0.0	0.0	8
1970	91.1	- 5.2	1.469	- 2.1	0.401		110.0	- 4.6	167.6	- 5.1	0.5	0.0	0.0	9
1971	79.5	-12.7	2.085	41.9	0.497	23.9	108.3	- 1.5	182.2	8.7	0.5	0.0	0.0	10
1972	74.6	- 6.2	2.379	14.1	0.576	15.9	107.3	- 0.9	194.0	6.5	0.5	0.0	0.0	11
1973	71.6	- 4.0	2.058	-13.5	0.567	- 1.6	111.8	4.2	198.9	2.5	1.0	100.0	0.0	12
1974	70.0	- 2.2	1.353	-34.3	0.329	-42.0	103.9	- 7.1	170.3	-14.4	2.5	150.0	0.0	13
1975	78.3	11.9	1.171	-13.5	0.213	-35.3	96.1	- 7.5	152.2	-10.6	2.6	4.0	0.0	14
1976	77.4	- 1.1	1.548	32.2	0.246	15.5	95.7	- 0.4	163.5	7.4	3.0	15.4	0.0	15
1977	74.3	- 4.0	2.002	29.3	0.277	12.6	92.7	- 3.1	173.4	6.1	6.0	100.0	1.0	16
1978	71.4	- 3.9	2.036	1.7	0.276	- 0.4	100.8	8.7	182.0	5.0	4.5	-25.0	1.0	17
1979	64.4	- 9.8	1.760	-13.6	0.277	0.4	103.3	2.5	179.3	- 1.5	5.0	11.1	1.0	18
1980	65.0	0.9	1.313	-25.4	0.222	-19.9	99.8	- 3.4	160.7	-10.4	4.5	10.0	1.0	19

[a] The time trend is a proxy in the econometric equation and represents changes due to the price of substitutes and energy, as well as changing input per unit of output.

insulation used per unit of housing and nonresidential construction from 1965 to 1980. The determinants directly included in Table 9-9 are the price of wool fiberglass relative to the total cost of new construction, the level of economic activity in the user industries, and a dummy variable for the income tax credit for the insulation of existing residential structures.

The data in Table 9-9 have been used in a formal, econometric analysis of the determinants of the demand for wool fiberglass. Appendix E discusses both the logic of the choice of each of these determinants of demand and also presents the equation used empirically to estimate demand. The elasticities of demand with respect to price and user-industry output that resulted from the analysis reported in Appendix E are presented in Table 9-10.

9.1.3.7 Supply Determinants. The quantity supplied in any industry depends in part on technical conditions of product and input prices. Since the wool fiberglass industry is oligopolistic, there is no supply curve; hence, it is inappropriate to discuss empirically the determinants of supply.[45] In the case of an oligopoly, the analysis focuses on the determinants of prices that are discretionary.[46-48]

9.1.3.8 Price Determinants. Prices in the wool fiberglass industry are determined by three variables: (1) unit costs of production, (2) demand pressures, and (3) discretionary pricing strategies of the firms in the industry and especially by OCF, the acknowledged price leader.

Table 9-11 summarizes the historical data from 1965 to 1979 for the first two determinants: costs and demand pressures. The optional pricing strategies for firms are available from the economic literature.[45-48] The role of OCF in setting prices in the wool fiberglass industry is discussed by Goldfarb.[13]

Appendix E discusses the logic of the choice of each of these determinants, as well as alternative approaches to empirical estimates of the price of wool fiberglass.

9.1.3.9 Financial Characteristics. Table 9-12 summarizes selected financial statistics for the four publicly held firms that produce wool fiberglass. Data on Guardian Industries are given only for 1981 since its fiberglass plant opened in late 1980.

TABLE 9-10. ELASTICITIES OF WOOL FIBERGLASS DEMAND WITH RESPECT TO PRICE AND USER-INDUSTRY OUTPUT[a]

Elasticity of the demand for wool fiberglass with respect to:	Estimate of elasticity
Price	-0.567
Housing starts	0.328
Retrofit market	0.158
Nonresidential construction	0.513

[a] Equation E-3 in Appendix E.

TABLE 9-11. DETERMINANTS OF THE PRICE OF WOOL FIBERGLASS, 1965 TO 1979[2,13,49-51]

Year	Costs										Demand pressures	
	Unit materials cost		Unit labor costs						Unit capital costs		Capacity utilization percent	Change in inventory/ sales $ 10³
			All employees		Production workers							
	$/ton	% change	$/ton	% change	$ wages/ manhour	Tons/ manhour	$/ton	% change	$/ton	% change		
1965	225.1		110.6		2.98	0.034	86.6		23.8		-	- 4.4
1966	244.1	8.4	123.9	12.0	3.09	0.032	95.9	10.7	28.9	21.4	-	18.6
1967	242.2	-0.8	126.7	2.3	3.29	0.033	99.4	3.6	34.5	19.4	-	7.1
1968	241.0	-0.5	127.3	0.5	3.57	0.036	100.1	0.7	39.4	14.2	-	4.0
1969	248.5	3.1	135.5	6.4	3.75	0.035	106.7	6.6	49.3	25.1	-	- 4.2
1970	261.8	5.4	143.9	6.2	3.92	0.035	112.3	5.2	64.6	31.0	-	11.7
1971	236.1	-9.8	128.4	-10.8	4.06	0.040	101.0	-10.1	53.0	-18.0	-	21.8
1972	231.6	-1.9	126.4	- 1.6	4.41	0.044	99.6	- 1.4	51.4	- 3.0	-	5.1
1973	233.6	0.9	129.1	2.1	4.69	0.046	101.5	1.9	53.2	3.5	97.0	9.5
1974	290.8	24.5	135.8	5.2	5.09	0.048	106.5	4.9	70.3	32.1	98.4	38.5
1975	371.1	27.6	147.7	8.8	5.44	0.048	112.7	5.8	102.3	45.5	81.5	-20.3
1976	374.8	1.0	157.0	6.3	5.98	0.049	123.0	9.1	94.7	- 7.4	80.5	-31.5
1977	356.3	-4.9	151.4	- 3.6	6.38	0.054	117.9	- 4.1	84.1	-11.2	88.9	28.4
1978	404.0	13.4	171.5	13.3	7.03	0.053	133.5	13.2	113.1	34.5	-	61.7
1979	423.1	4.7	181.2	5.7	7.94	0.056	142.4	6.7	129.1	14.1	83.5	-42.6
Annual Compound Growth Rates												
1965 to 1979	4.3	-	3.3	-	6.8	3.4	3.4	-	11.9	-	-	-
1970 to 1979	4.9	-	2.3	-	7.3	4.8	2.4	-	7.2	-	-	-
1975 to 1979	2.7	-	4.2	-	7.9	3.1	4.8	-	4.8	-	-	-

TABLE 9-12. FINANCIAL CHARACTERISTICS OF PUBLICLY HELD CORPORATIONS PRODUCING WOOL FIBERGLASS[6-12]

	Companies[a]							
	CertainTeed		Guardian Industries[b]		Manville		Owens-Corning	
Year	Company total	Business segment with wool fiberglass[c]	Company total	Business segment with wool fiberglass[d]	Company total	Business segment with wool fiberglass[e]	Company total	Business segment with wool fiberglass[f]
				Sales ($ 10^6)				
1978	895.4	280.2	-	-	1,676.6	514.3	1,853.1	1,418.3
1979	916.2	259.7	-	-	2,297.4	573.2	2,245.2	1,734.5
1980	868.2	289.1	-	-	2,292.4	610.1	2,285.1	1,775.6
1981	891.5	334.6	364.5	-	2,220.7	625.3	2,375.1	1,779.1
				Profits before taxes ($ 10^6)				
1978	89.0	31.5	-	-	260.3	107.3	228.3	205.2
1979	23.7	-13.3	-	-	280.3	95.7	178.7	186.8
1980	- 2.4	2.2	-	-	222.6	91.1	53.2	124.5
1981	-26.5	14.1	52.9	-	198.3	89.8	50.0	57.3
				Assets ($ 10^6)				
1978	669.7	307.6	-	-	2,217.0	474.6	1,209.8	611.5
1979	726.5	341.0	-	-	2,323.2	561.6	1,501.6	741.7
1980	693.5	316.5	-	-	2,338.2	575.4	1,533.8	754.6
1981	663.7	301.2	386.3	-	2,297.8	566.9	1,601.9	730.8

(Continued)

TABLE 9-12, continued

	CertainTeed		Guardian Industries[b]		Manville		Owens-Corning	
Year	Company total	Business segment with wool fiberglass[c]	Company total	Business segment with wool fiberglass[d]	Company total	Business segment with wool fiberglass[e]	Company total	Business segment with wool fiberglass[f]
				Return on sales (percent)				
1978	9.9	11.2	-	-	15.5	20.9	12.3	14.5
1979	2.6	-5.1	-	-	12.2	16.7	8.0	10.8
1980	-0.3	0.8	-	-	9.7	14.9	2.3	7.0
1981	-3.0	4.2	14.5	-	8.9	14.4	2.1	3.2
				Before tax return on investment (percent)				
1978	13.3	10.2	-	-	11.7	22.6	18.9	33.6
1979	3.3	-3.9	-	-	12.1	17.0	11.9	25.2
1980	-0.3	0.7	-	-	9.5	15.8	3.5	16.5
1981	-4.0	4.7	13.7	-	8.6	15.8	3.1	7.8

[a] Excludes Knauf, which is privately owned.

[b] Data from 1978 to 1980 are not applicable because Guardian Industries opened its wool fiberglass plant in late 1980.

[c] Wool fiberglass is the major component of CertainTeed's "Fiber Glass Products" business segment.

[d] Wool fiberglass is part of Guardian's "Insulation Operations," but no financial data are provided for this business segment which includes a mineral wool plant (opened in 1978) and a wool fiberglass plant (opened in late 1980).

[e] Wool fiberglass is the major component of Manville's "Fiber Glass Products" business segment. This business segment also includes a small amount of output of chopped fiberglass strand used as a reinforcing material in roof shingles and in roll roofing, which is produced in a separate business segment, "Roofing Products."

[f] Wool fiberglass is part of Owens-Corning's "Insulation and Construction" business segment, which also produces roofing products and includes a contracting division.

CertainTeed, Manville, and OCF all show a lower profit margin on sales and assets in 1980 and 1981 than for 1978 and 1979. This is attributable to the depressed conditions in the housing market, which have reduced capacity utilization.

9.1.4 Growth Projections

9.1.4.1 Demand Projections

9.1.4.1.1 Projections of demand:five other studies. Several projections of demand for thermal insulation and for wool fiberglass are summarized in Table 9-13. For the purposes of this analysis, these projections have the shortcoming of not predicting demand sufficiently far into the future, but they are helpful in assessing near-term growth in demand.

Thermal insulation. Frost and Sullivan, Ltd., provide the most optimistic estimates of the growth in thermal insulation. They foresee an 11 percent annual growth in real output up to 1982 and then a tapering off to slightly less than 7.0 percent into 1985.[52] Hull and Co. expect the demand for thermal insulation to increase 7.5 percent annually into 1983. This strong demand is seen as a direct result of continually rising energy costs although moderated somewhat by the current low level of new residential construction.[53]

According to a recent marketing study undertaken by Business Communications, the insulation industry should grow at an average annual rate of 6.0 percent (in terms of pounds; 7.5 percent on a constant dollar basis) until 1982, then level off as retrofit requirements are met and new construction insulation standards are established.[54]

Wool fiberglass insulation. As is evident from Table 9-13, the growth projections for wool fiberglass insulation do not differ significantly from those for thermal insulation because fiberglass represents approximately 60 percent of the thermal insulation industry.

According to Hull and Co., wool fiberglass will exhibit a lower growth rate than the industry average (i.e., less than 7.5 percent annually) into 1983.[53] While fiberglass will continue to dominate the overall insulation market, Hull and Co. foresee the greatest growth in foam insulation in exterior residential sheathing and industrial roofing applications. Finally, Merrill Lynch expects the industry to experience a resurgence at a 6 percent annual pace until 1983, then a flatten-

TABLE 9-13. GROWTH PROJECTIONS BY TIME PERIOD AND BY SOURCE[52-55]

Industry	Projected annual growth rate[a] (%)	Time horizon	Source
Thermal insulation[b]	11.0 < 7.0	1980-1982 1983-1985	Frost and Sullivan, Ltd.
Thermal insulation[b]	7.5	1980-1983	Hull and Co
Thermal insulation[b]	6.0	1979-1982	Business Communications Co
Fiberglass insulation	< 7.5	1980-1983	Hull and Co.
Fiberglass insulation	6.0	1980-1984	Merrill Lynch

[a] Growth rate of real output in physical units.

[b] Fiberglass represents 60 percent of the thermal insulation market.

ing out of demand. Capacity utilization should rise from the 1981 level of 66.6 percent to almost 94 percent by 1984.[55]

9.1.4.1.2 Projections of demand: empirical demand equations. Projections of the growth in demand for wool fiberglass have been made in this analysis using the empirical demand equation estimated by econometric techniques and reported in Appendix E.

To make these projections, assumptions must be made about the future values of the determinants of demand. The values assumed for the independent variables (determinants) are in Table 9-14. Background data on the selection of two alternate assumptions about the prices for wool fiberglass are in Table 9-15. Projections for user-industry activity variables and the cost of construction are drawn from a single source, the Wharton Annual Model.[56] This has two advantages. First, the variables are internally consistent because the model is a large econometric model of the economy with an embedded input-output system. This means that growth in user-industry activities, costs, and prices are internally consistent over the business cycle and during longer term growth. Second, it represents a consensus among a large group of empirically oriented macroeconomists, since other econometric models such as those by Data Resources and Chase Econometrics reach similar conclusions about future economic conditions.[57] A possible disadvantage of the Wharton Model is that it forecasts a pause in the economy in 1986 as part of its stock adjustment process; others may find it more plausible to assume that housing starts continue to increase in 1986 rather than decline as a result of a "pause" that cannot be forecasted.

Several exogenous assumptions about the future behavior of the price of wool fiberglass are plausible. Table 9-15 gave four results, which can be reduced to two alternatives. One is the Goldfarb/Wharton alternative, in which prices increase 8 to 9 percent a year; this is called the "high-price growth" case. The other is the Frost and Sullivan/Trend Projection alternative, in which prices grow at their historical rate of 4.8 percent a year; this is the base case that assumes a low growth in price increases.

Table 9-16 presents projections of output from 1980 to 1991 using Equation E-3 presented in Appendix E and alternative assumptions about

TABLE 9-14. ASSUMPTIONS ABOUT THE DETERMINANTS OF THE DEMAND FOR WOOL FIBERGLASS, 1980 TO 1991, ECONOMETRIC APPROACH[56,58]

	Housing starts		Mobile homes		Nonresidential construction		Total new construction		Retrofit market		Price index of wool fiberglass					Price index of cost of construction	
											High price growth		Low price growth				
Year	10^6 units	% change	10^6 units	% change	10^9 1977 $	% change	10^9 1977 $	% change	10^6 units	% change	1967 = 100	% change	1967 = 100	% change	Time trend	1967 = 100	% change
1980	1.313	-25.4	0.222	-19.9	99.8	- 3.4	160.7	-10.4	4.5	10.0	201.5	13.2	201.5	13.2	22	309.7	11.2
1981	1.119	-14.8	0.262	18.0	101.3	1.5	160.7	0.0	4.1	-8.8	224.9	11.6	224.9	11.6	23	329.8	6.5
1982[a]	1.185	5.8	0.281	7.3	100.4	- 0.9	158.6	- 1.3	3.8	-7.3	244.5	8.7	235.7	4.8	24	358.2	8.6
1983[a]	1.623	37.0	0.293	4.3	107.0	6.6	175.1	10.4	3.5	-7.9	262.3	7.3	247.0	4.8	25	384.0	7.2
1984[a]	1.963	21.0	0.408	39.2	112.2	4.9	189.5	8.2	3.2	-8.6	283.8	8.2	258.9	4.8	26	415.5	8.2
1985[a]	2.103	7.1	0.411	0.7	116.7	4.0	197.6	4.3	2.9	-9.4	308.2	8.6	271.3	4.8	27	450.4	8.4
1986[a]	1.883	-10.5	0.442	7.5	119.2	2.1	195.6	- 1.0	2.9	0.0	337.5	9.5	284.3	4.8	28	490.5	8.9
1987[a]	1.801	- 4.4	0.517	17.0	124.7	4.6	202.1	3.3	2.8	-3.4	369.2	9.4	297.9	4.8	29	534.2	8.9
1988[a]	1.964	9.0	0.490	- 5.4	130.1	4.3	212.4	5.1	2.8	0.0	399.1	8.1	312.2	4.8	30	579.6	8.5
1989[a]	2.008	2.2	0.508	3.8	135.8	4.4	220.7	3.9	2.7	-3.6	431.0	8.0	327.2	4.8	31	629.4	8.6
1990[a]	2.086	3.9	0.470	- 7.5	141.2	4.0	228.9	3.7	2.7	0.0	466.8	8.3	342.9	4.8	32	684.2	8.7
1991[a]	1.971	- 5.5	0.482	2.6	147.8	4.7	235.5	2.9	2.7	0.0	501.3	7.4	359.4	4.8	33	743.7	8.7

[a] Forecasts.

TABLE 9-15. ALTERNATIVE FORECASTS OF THE PRICE OF WOOL FIBERGLASS[5, 56, 59]

Year	Goldfarb/Merrill Lynch		Wharton Econometrics		Frost and Sullivan		Trend Projection[a]	
	(1967 = 100)	% change	(1967 = 100)	% change	(1967 = 100)	% change	(1967 = 100)	% change
1980	201.5	-	201.5	-	201.5	-	201.5	-
1981	221.7[b]	10.0[b]	224.9	11.6	224.9	11.6	224.9	11.6
1982[b]	239.4	8.0	244.5	8.7	235.7	4.8	235.7	4.8
1983[b]	258.6	8.0	262.3	7.3	247.0	4.8	247.0	4.8
1984[b]	279.2	8.0	283.8	8.2	258.9	4.8	258.9	4.8
1985[b]	-	-	308.2	8.6	271.3	4.8	271.3	4.8
1986[b]	-	-	337.5	9.5	284.3	4.8	284.3	4.8
1987[b]	-	-	369.2	9.4	297.9	4.8	297.9	4.8
1988[b]	-	-	399.1	8.1	312.2	4.8	312.2	4.8
1989[b]	-	-	431.0	8.0	327.2	4.8	327.2	4.8
1990[b]	-	-	466.8	8.3	342.9	4.8	342.9	4.8
1991[b]	-	-	501.3	7.4	359.4	4.8	359.4	4.8

[a] The trend projection is based on an econometric equation which says prices are a function of time. For a discussion of this, see Appendix E, Section E.2.

[b] Forecasts.

TABLE 9-16. FORECASTS OF THE DEMAND FOR WOOL FIBERGLASS (1980 TO 1991) UNDER HIGH AND LOW PRICE ESTIMATES USING ECONOMETRIC TECHNIQUES[a]

	Alternative 1 wool fiberglass output under high price forecast[b]			Base case wool fiberglass output under low price forecast[c]		
Year	(Gg)	(10^6 lb)	(% growth)	(Gg)	(10^6 lb)	(% growth)
1980[d]	1,176	2,590.1	-	1,176	2,590.1	-
1981[d]	1,110	2,445.9	-5.6	1,110	2,445.9	-5.6
1982[e]	1,145	2,521.5	3.1	1,169	2,574.5	5.3
1983[e]	1,332	2,933.5	16.3	1,378	3,035.1	17.9
1984[e]	1,474	3,246.7	10.7	1,553	3,420.1	12.7
1985[e]	1,557	3,430.3	5.6	1,674	3,687,3	7.8
1986[e]	1,558	3,431.2	0.0	1,717	3,781.5	2.6
1987[e]	1,604	3,533.1	3.0	1,811	3,990.0	5.5
1988[e]	1,740	3,831.6	8.4	1,999	4,403.7	10.4
1989[e]	1,839	4,050.1	5.7	2,150	4,734.6	7.5
1990[e]	1,956	4,315.3	6.5	2,333	5,139.6	8.6
1991[e]	2,040	4,493.6	4.1	2,463	5,426.2	5.6
Annual compound growth rates						
1981 to 1991		5.7	-		7.7	-
1981 to 1984		7.8	-		9.7	-
1985 to 1991		4.6	-		6.7	-

[a] Equation E-3 in Appendix E.

[b] High estimates of price growth are from Goldfarb and Wharton, reported in Table 9-15.

[c] Low estimates of price growth are from Frost and Sullivan and trend projections, reported in Table 9-15.

[d] The actual value in 1980 was 2,622.1 x 10^6 lb and in 1981, it was 2,449.4 x 10^6 lb.

[e] Forecasts.

future price increases for wool fiberglass. In both projections, growth is higher in the earlier part of the forecast period, particularly 1983 and 1984, than in the second half of the forecast period. This is largely because housing starts will be buoyed by a backing of demand and demographic factors but also because the retrofit market is projected to be larger in the early 1980's than later in the forecast period.

The lower growth scenario for price changes to 1991 is more reasonable for three reasons. First, the current disinflation in the economy suggests that unit costs (labor and materials) will rise at a lower rate than in recent years, hence, the price of wool fiberglass will increase at a lower rate. Second, use of the lower price projections preserves the historical trend in the price of wool fiberglass relative to the cost of construction, where the trend in this price term is downward. Third, use of the lower price projections results in similar forecasts from 1981 to 1984 to those made by Goldfarb. As a result, the price changes forecast under this scenario are taken to represent the base case in the projections of new sources in Section 9.1.4.3.

9.1.4.1.5 Projections of demand: technical coefficients/ad hoc techniques. Projections of the demand for wool fiberglass can also be made from 1980 to 1984 by using technical coefficients and ad hoc techniques. Goldfarb's estimates reported in Table E-4 of Appendix E are one example. An alternative forecast, which primarily uses Frost and Sullivan data, is in Table 9-17. The latter projects a higher rate of growth in demand than the base case. However, this was not used in the analysis, because we believe the projections are unrealistically high.

9.1.4.1.6. Growth projections. The growth projections that seem most likely to occur are those in the base case of the empirical demand forecasts (Table 9-16), where the price of wool fiberglass is assumed to increase at 4.8 percent a year until 1991. These forecasts are, therefore, used as the basis for the projections of the number of new sources and replacements of existing sources in Section 9.1.4.

This price forecast is consistent with past experience in the industry, with recent disinflation in the economy (which is leading econometric forecasters to revise price projections for the eighties sharply downward) and with past behavior in the relevant price measure, i.e., the price of wool fiberglass divided by the cost of construction.[57] These projections of

TABLE 9-17. ALTERNATIVE FORECASTS OF THE DEMAND FOR WOOL FIBERGLASS, 1980 TO 1984 USING TECHNICAL COEFFICIENTS/AD HOC TECHNIQUES[44,55,58]

	New residential construction except mobile homes						New construction of mobile homes					
	Housing starts (10^6 units)	% Using fiber-glass	Insulation per unit		Total demand for fiberglass in new housing		Shipments in mobile homes (10^6 units)	% Using fiber-glass	Insulation per unit		Total demand for fiberglass in mobile homes	
Year			(Kg)	(lb)	(Gg)	(10^6 lb)			(lb)	(Kg)	(Gg)	(10^6 lb)
1980	1.313	64.4	408	900	345	761.0	0.222	87.5	543	246	48	105.5
1981[a]	1.119	65.3	476	1,050	348	767.2	0.262	87.5	554	251	58	127.0
1982[a]	1.185	66.2	544	1,200	427	941.4	0.281	87.5	565	256	63	138.9
1983[a]	1.623	67.1	605	1,333	659	1,451.7	0.293	87.5	576	261	67	147.7
1984[a]	1.963	68.0	665	1,466	888	1,956.9	0.408	87.5	588	267	95	209.9

Retrofit of existing houses											
Homes retrofitted with insulation (10^6 units)	% using fiber-glass	Insulation per unit		Total demand for fiberglass in retro-fitted market		Total demand for wool fiberglass for thermal insulation of residential structures		All other demand		Total demand	
		(Kg)	(lb)	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)
4.5	72.0	119	263	387	852.1	780	1,718.6	353	776	1,133	2,495
4.1	73.5	131	289	395	870.9	801	1,765.1	444	979	1,245	2,744
3.8	74.0	143	315	402	885.8	892	1,966.1	446	983	1,338	2,949
3.5	75.0	151	333	397	874.1	1,123	2,473.5	497	1,095	1,620	3,568
3.2	75.0	160	352	384	844.8	1,367	3,011.6	557	1,227	1,924	4,239

NA = Not available.

[a] Forecasts.

demand to 1984 are in agreement with independent estimates through 1984 made by Goldfarb using a different methodology. A comparison of these two forecasts is presented in Table 9-18.

Other scenarios are possible. One is a lower growth rate obtained from the empirical equation estimated by econometric techniques but with the higher price growth scenarios (Alternative 1 in Table 9-16). In that case, 1984 demand is 1,474 Gg (3,247 x 10^6 lb), and 1991 demand will be only 2,040 Gg (4,494 x 10^6 lb). The other is a higher growth rate using technical coefficients and ad hoc techniques, as summarized in Table 9-17. In that case, 1984 demand is 1,924 Gg (4,239 x 10^6 lb). Thus, the low-growth-in-demand alternative scenario results in 79 fewer Gg (173 x 10^6 lb) being produced in 1984 than the base case, and the high-growth-in-demand scenario results in 371 more Gg (819 x 10^6 lb) being produced in 1984 than in the base case.

9.1.4.2 Capacity Projections. Capacity projections can be made on the basis of current and projected output, current and historical capacity utilization rates, and leadtimes involved in adding new capacity.

The wool fiberglass industry is estimated to have operated at 66.6 percent of capacity in 1981, a figure considerably below the historical average of 86 percent calculated from the data in Table 9-11.[13] This means that initially, as the industry emerges from its current recession, growth in demand can be met without any additions to capacity.

The lead time for additions to capacity varies, depending upon whether it involves adding an additional line to an existing plant (the lead time is 12 to 18 months) or building an entirely new plant (the lead time is 24 to 36 months).[24]

Table 9-19 summarizes capacity projections to 1991. Capacity is estimated to be 2,864 Gg (6,309 x 10^6 lb) in 1991 compared to 1,632 Gg (3,595 x 10^6 lb) in 1980, implying an annual compound growth rate in capacity of 5.2 percent over the period.

9.1.4.3 New Sources. The number of new sources is comprised of two components, sources to accommodate growth in demand and sources to replace old and obsolete facilities. Table 9-19 presents annual capacity levels and indicates the growth necessary to fulfill anticipated demand. Replacement rates are calculated assuming a 40-year plant or line life

TABLE 9-18. GROWTH PROJECTIONS, 1980 TO 1991

	Base case[a]		Goldfarb[b]		Difference		
Year	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)	(Gg[c])	(10^6 lb[c])	(Percent[d])
1980[e]	1,176	2,590.1	1,179	2,596	-3	-5.9	0.2
1981[e]	1,110	2,445.9	1,162	2,560	-52	-114.1	4.5
1982[e]	1,169	2,574.5	1,283	2,825	-114	-250.5	8.9
1983[e]	1,378	3,035.1	1,480	3,260	-102	-224.9	6.9
1984[e]	1,553	3,420.1	1,609	3,545	-56	-124.9	3.5
1985[e]	1,674	3,687.3					
1986[e]	1,717	3,781.5					
1987[e]	1,811	3,990.0					
1988[e]	1,999	4,403.7					
1989[e]	2,150	4,734.6					
1990[e]	2,333	5,139.6					
1991[e]	2,463	5,426.2					

[a] Table 9-16.
[b] Table E-4 in Appendix E.
[c] Base case estimate minus Goldfarb estimate.
[d] Millions of Gg in Goldfarb estimate minus millions of Gg in base case divided by Goldfarb estimate times 100.
[e] Forecasts.

TABLE 9-19. OUTPUT, CAPACITY, AND CAPACITY UTILIZATION, 1980 TO 1991

Year	Shipments[a] (Gg)	Shipments[a] (10⁶ lb)	Capacity[b] (Gg)	Capacity[b] (10⁶ lb)	Capacity utilization[c] (percent)
1980	1,190	2,622	1,632	3,595	72.9
1981	1,112	2,449	1,668	3,675	66.6
1982[d]	1,169	2,574	1,628	3,585	71.8
1983[d]	1,378	3,035	1,640	3,613	84.0
1984[d]	1,553	3,420	1,655	3,646	93.8
1985[d]	1,674	3,687	1,946	4,287	86.0
1986[d]	1,717	3,781	1,997	4,398	86.0
1987[d]	1,811	3,990	2,107	4,640	86.0
1988[d]	1,999	4,404	2,325	5,121	86.0
1989[d]	2,150	4,735	2,500	5,506	86.0
1990[d]	2,333	5,140	2,714	5,977	86.0
1991[d]	2,463	5,426	2,864	6,309	86.0

[a] Actual data for 1980 and 1981 and estimated demand for wool fiberglass, 1982 to 1991, using the base case in Table 9-18.

[b] Capacity for 1980 to 1984 is from Goldfarb. From 1985 to 1991, it is shipments divided by capacity utilization times 100.

[c] Capacity utilizations from 1980 to 1984 is shipments divided by capacity. From 1985 to 1991, capacity utilization is assumed to be at the historical average of 86.0 percent.

[d] Forecasts.

that necessitates a 2.5 percent annual replacement rate. With the 1982 capacity level of 1,629 Gg (3585.9 x 10^6 lbs) per year, 40.7 Gg (89.6 x 10^6 lbs) of capacity must be built annually to provide the necessary replacement capacity.

Over the 1978 to 1981 period, the ratio of new plants to expansions at existing sites has been 4:5 (see Table 9-20). Since no other information is available to project the ratio of future new plants to expansions, the analysis assumes in Section 9.3 below that the 4:5 ratio will continue for capacity additions in the forecast period. Table 9-21 is constructed on the premise that required growth capacity is provided by the 4:5 ratio of medium-sized plants (105 Gg/yr [231.3 x 10^6 lbs]) to medium-sized lines (34 Gg/yr [74.9 x 10^6 lbs]) and replacement units would consist of medium-sized lines. This results in an estimate of 3 new plants and 17 new lines in the 1983-1988 period and 2 new plants plus 13 new lines in the 1988-1991 period.

Because future additions to capacity may include other options besides medium plants and medium lines, an extreme scenario was examined that consists of all small plants and all small lines each with an annual capacity of 18 Gg (39.6 x 10^6 lbs). The 1983-1988 period would then produce 49 units, 17 of which would be small plants and 32 of which would be small lines. The 1988-1991 period would see the construction of 13 small plants and 24 small lines. This alternate scenario provides the most severe economic impact that could occur due to the construction of the projected new capacity.

9.2. ECONOMIC IMPACT ANALYSIS

In the following sections, the potential economic impact of the regulatory alternatives presented in Chapter 6 are examined. This analysis includes an examination of the effects on the price, profitability, and capital availability of control technologies for rotary spin manufacturing lines (RS) that are well demonstrated and cost effective. The following regulatory alternatives and control device configurations for RS manufacturing lines satisfy these criteria:

I	Scrubber-incinerator (Base Case)
III	Scrubber-scrubber
III	Wet electrostatic precipitator (ESP)-ESP
IV	ESP-ESP-ESP Scrubber-Scrubber-Scrubber

TABLE 9-20. NEW AND EXPANDED PLANTS, 1978 TO 1981[5,23,60-62]

Company
New grass roots plants
Manville
CertainTeed, 1979
Manville, 1979
Guardian Industries, 1980
Expansions[a]
Owens-Corning, 1978
Owens-Corning, 1978
CertainTeed, 1978
Manville, 1981

[a] Includes one other expansion that cannot be cited due to confidentiality.

TABLE 9-21. PROJECTION OF NEW PRODUCTION FACILITIES

Period	Growth		Replacement		Total		New Units	
	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)	Plants	Lines
1983-1988[b]	685	1,508.8	203.5	447.1	888.5	1,957.0	3	17
1988-1991[c]	539	1,187.2	122.1	268.9	661.1	1,456.2	2	13

[a] Growth is based on capacity projections in Table 9-19.

[b] $\frac{685\ (4)}{105\ (9)}$ = 2.9 rounded to 3 $\frac{888.5 - 315}{34}$ = 16.9 rounded to 17

[c] $\frac{539\ (4)}{105\ (9)}$ = 2.3 rounded to 2 $\frac{661.1 - 210}{34}$ = 13.3 rounded to 13

The small flame attenuation (FA) model line is also included in the analysis.

9.2.1 Maximum Price Increases

The maximum price increase is the price pass-through that would occur if the firm passed all control costs associated with the regulatory alternatives through to the consumer in the form of higher prices. It is thus a "worst case" from the point of view of the consumer.

The maximum price increase is the incremental annualized cost of control above the baseline for any regulatory alternative divided by the revenues generated by that model plant or line. It is thus assumed in the analysis that firms will increase operating income to maintain the preregulatory return on investment after imposition of any standard.

Table 9-22 summarizes the maximum price increases by regulatory alternative and by model line and plant size at each of two levels of capacity utilization, 86 percent and 70 percent. The 86 percent capacity utilization is the historical average for the industry, whereas 66.6 percent is the current level of capacity utilization.

As the results in Table 9-22 indicate, all of the maximum price increases for the rotary spin process are small (less than 1 percent). In the case of the small model flame attentuation line, however, the maximum price increase varies from a low of 3.43 percent to a high of 19.12 percent.

9.2.2 Profitability

Return on investment (ROI) calculations representing full absorption of all control costs have customarily been presented as the opposite bound to the full pass through of costs to the consumer. However, full absorption is a very unlikely case in this industry. Even though product substitution is always a threat should prices rise too high, firms in an industry dominated by only a few large companies have much greater freedom to vary prices upward. Otherwise, they can wait until growth in demand pushes prices up. If greater demand does not materialize, there is no point in building a new plant and thus no requirement to accept lower rates of return.

Table 9-23 presents the baseline ROI calculations and Table 9-24 the effects of full absorption of control costs for the regulatory alternatives under consideration. As in the case of the price increase calculations, two levels of capacity utilization are considered. As might be expected,

TABLE 9-22. MAXIMUM PERCENT PRICE INCREASES OF SELECTED REGULATORY ALTERNATIVES[a]

Model line or plant RS or FA[b]	Size	Reg. alt	Control equipment[c]	Maximum percent price increase (percent) at 86 percent capacity utilization	Maximum percent price increase (percent) at 70 percent capacity utilization
Plants-RS	Small				
		III	Scrub., Scrub.	0.26	0.32
			ESP, ESP	0.32	0.39
		IV	ESP, ESP, ESP	0.47	0.57
			Scrub., Scrub., Scrub.	0.48	0.59
	Medium	III	Scrub., Scrub.,	0.39	0.48
			ESP, ESP	0.43	0.63
		IV	ESP, ESP, ESP	0.52	0.63
			Scrub., Scrub., Scrub.	0.49	0.60
	Large	III	Scrub., Scrub.	0.30	0.37
		III	ESP, ESP	0.30	0.37
		IV	ESP, ESP, ESP	0.39	0.48
			Scrub., Scrub., Scrub.	0.41	0.50
Lines-RS	Small	III	Scrub., Scrub.	0.26	0.32
			ESP, ESP	0.32	0.39
		IV	ESP, ESP, ESP	0.47	0.57
			Scrub., Scrub., Scrub.	0.48	0.59

(Continued)

TABLE 9-22, continued

Model line or plant RS or FA[b]	Size	Reg. alt	Control equipment[c]	Maximum percent price increase (percent) at 86 percent capacity utilization	Maximum percent price increase (percent) at 70 percent capacity utilization
	Medium	III	Scrub., Scrub	0.22	0.27
			ESP, ESP	0.24	0.30
		IV	ESP, ESP, ESP	0.35	0.43
			Scrub., Scrub., Scrub.	0.34	0.42
	Large	III	Scrub., Scrub	0.33	0.41
			ESP, ESP	0.32	0.39
		IV	ESP, ESP, ESP	0.39	0.48
			Scrub., Scrub., Scrub.	0.41	0.51
Model Line-FA					
	Small	III	HVAF, HVAF	3.43	4.21
		IV	HVAF	15.52	19.12

[a] Maximum price increases are the incremental annualized costs of pollution control systems above the baseline divided by the revenue generated by a model line or plant times 100. Revenue is capacity times the capacity utilization rate (.86 or .70) times .99 times the January 1982 price of wool. Shipments are assumed to be 99 percent of production, an historical average for the industry. The January 1982 price of wool fiberglass of \$1.34/kg (\$0.61/lb) is the implicit 1981 price of \$1.33/kg (\$0.60/lb) times a one percent increase for January 1982.

[b] RS = rotary spin FA = flame attenuation.

[c] Scrub. = venturi scrubber HVAF = high velocity air filter ESP = wet electrostatic precipitator.

TABLE 9-23. RETURN ON INVESTMENT OF MODEL PLANTS AND LINES WITH BASELINE POLLUTION EQUIPMENT (REG. ALT. I)[a]

Capacity utilization (percent)	Category	Model plant size-RS[b]			Model line size-FA[b]
		Small	Medium	Large	Small
86.0%	Total investment ($\$10^3$)	29,297	93,624	131,738	2,450
	Annual revenue ($\$10^3$)[c]	20,536	119,222	173,413	5,134
	Annual costs ($\$10^3$)[d]	17,340	88,113	128,575	4,214
	Profits before Fed. taxes[e]	3,196	31,109	44,838	920
	Federal taxes ($\$10^3$)[f]	1,470	14,310	20,625	423
	Net profits ($\$10^3$)[g]	1,726	16,799	24,213	497
	Before Tax ROI (%)[h]	10.9	33.2	34.0	37.6
	After tax ROI (%)[i]	5.9	17.9	18.4	20.3
70.0%	Before tax ROI (%)[h]	4.2	20.8	21.3	22.7
	After tax ROI (%)[i]	2.2	11.2	11.5	12.3

[a] Return on investment (ROI) is profits before or after taxes divided by the investment required to generate that return. ROI has been calculated at 86 and 70 percent of capacity utilization. The historical average for the industry is 86 percent capacity utilization, but the industry is currently operating at 70 percent. Seventy percent is not a desirable utilization rate and as a result ROIs are low.

[b] RS = rotary spin FA = flame attenuation

[c] Annual revenue is capacity times the capacity utilization rate (.86 or .70) times .99 times the January, 1982, price of wool fiberglass. Shipments are assumed to be 99 percent of production, the historical average for the industry. The January 1982 price of wool fiberglass of \$1.34/kg (\$0.61/lb) is the implicit 1981 price of \$1.33/kg (\$0.60/lb) times a one percent increase for January, 1982.

[d] Annual costs include operating costs, general and administrative expenses, state and local taxes, depreciation and interest. Direct operating costs (variable costs) for investment without pollution control are assumed to be .86 or .70 of total direct operating costs to reflect the levels of capacity utilization; indirect operating costs (fixed costs) are assumed to be 1.00 of total indirect operating costs. Costs of baseline pollution control (both variable and fixed costs) are assumed to be 100 percent even though capacity utilization levels are 86 and 70 percent. Thus, this is a conservative assumption which tends to overstate pollution control costs.

[e] Annual revenue minus annual costs.

[f] Profits before taxes times .46.

[g] Profits before Federal taxes minus Federal taxes.

[h] Profits before Federal income tax divided by total investment.

[i] Net profits divided by total investment.

TABLE 9-24. AFTER TAX RETURN ON INVESTMENT FOR SELECTED REGULATORY ALTERNATIVES[a]

Model Line or plant RS or FA[b]	Size	Reg. alt	Control equipment[c]	Return on investment: 86 percent capacity utilization	Return on investment: 70 percent capacity utilization
Plants-RS					
	Small	I[d]	Scrub, Inc.	5.9	2.2
		III	Scrub., Scrub.	5.7	2.1
			ESP, ESP	5.5	2.0
		IV	ESP, ESP, ESP	5.4	2.0
			Scrub., Scrub., Scrub.	5.6	2.0
	Medium	I[d]	Scrub, Inc.	17.9	11.2
		III	Scrub., Scrub.	17.5	10.9
			ESP, ESP	16.8	10.5
		IV	ESP, ESP, ESP	16.7	10.4
			Scrub., Scrub., Scrub.	17.4	10.8
	Large	I[d]	Scrub, Inc.	18.4	11.5
		III	Scrub., Scrub.	17.9	11.1
			ESP, ESP	17.3	10.7
		IV	ESP, ESP, ESP	17.1	10.6
			Scrub., Scrub., Scrub.	17.9	11.1
Model Line-FA					
	Small	I[d]	Uncontrolled	20.3	12.3
		III	HVAF, HVAF	13.8	6.0
		IV	HVAF	1.6	NA[e]

[a] Return on investment (ROI) is profits after taxes divided by the investment used to generate these profits. For an example of how ROI is calculated for model lines and plants, see Table 9-23. Costs of pollution control (both variable and fixed costs) are assumed to be 100 percent even though capacity utilization levels are 86 and 70 percent.

[b] RS = rotary spin FA = flame attenuation

[c] Scrub. = venturi scrubber HVAF = high velocity air filter ESP = wet electrostatic precipitator. Inc. = Incinerator.

[d] Regulatory baseline.

[e] NA = not applicable, because after tax profits are negative.

changes in capacity utilization show a far greater effect on ROI than control cost absorption.

9.2.3 Capital Availability

Having forecasted the expected number of new sources and estimated the costs of new capacity and the required abatement capital, it is useful to inquire whether the wool fiberglass industry will face any significant difficulties in raising the funds necessary to pay for the abatement capital required by the regulatory alternatives. Despite the current recession and Manville's asbestos liability problems, there appears to be little doubt that the industry can raise the capital necessary to comply with the regulatory alternatives. Since the distribution of new capacity across the five firms in the industry cannot reasonably be predicted, the focus of this analysis of the capital availability must necessarily be at the industry level. However, the analysis proceeds by examining each firm individually to assess its access to additional capital, and then a general conclusion is drawn about the industry's ability to finance the projected abatement capital needs.

Table 9-21 shows that between 1983 and 1988 the United States wool fiberglass industry is projected to add 888.5 Gg (1,957.0 x 10^6 lb) of new capacity due to both demand growth and replacement. Table 9-25 examines for two cases the types of plants and lines that the capacity expansion would require, as well as the associated costs. Under Case One (best estimate) 3 medium-sized plants (105 Gg/yr [231.3 x 10^6 lb/yr]) and 17 medium-sized lines (34 Gg/yr [74.9 x 10^6 lb/yr]) would be added. These additions would require $599 million in new plant capacity, plus $41 million in pollution control equipment capital, for a total of $641 million. Under Case Two (alternate case) 17 small plants (18 Gg/yr [39.6 x 10^6 lb/yr]) and 32 small lines (18 Gg/yr [39.6 x 10^6 lb/yr]) would be acquired, with a plant capital cost of $828 million and abatement capital costs of $76 million, totalling $904 million.

Table 9-26 shows that Owens-Corning's share of wool fiberglass capacity in 1980 was 63.0 percent. Approximately 75.0 percent of its revenues were from the sale of wool fiberglass. In 1981, it possessed a long-term debt to capitalization ratio of 26.8 percent, the lowest in the industry. Table 9-28 shows that OCF's capital spending has consistently

TABLE 9-25. COSTS OF NEW PRODUCTION FACILITIES 1983-1988[a]

Cases	No. medium plants	No. small plants	No. medium lines	No. small lines	Capital costs without abatement[b] ($ x 10^6)	Abatement capital costs[c] ($ x 10^6)	Total capital costs ($ x 10^6)
One	3	0	17	0	599.4	41.4	640.8
Two	0	17	0	32	828.1	76.4	904.5

[a] 888.5 Gg (1,957.0 x 10^6 lb) of new source capacity is projected to be needed.

[b] Includes baseline control costs.

[c] Based on Alternative III (ESP, ESP).

TABLE 9-26. WOOL FIBERGLASS REVENUE SHARES AND CAPACITY SHARES

Firm	Share of 1981 revenue from wool fiberglass (%)[a]	1980 share of capacity (%)[b]
Owens-Corning	75	63.0
CertainTeed	38	20.3
Manville	28	15.6
Knauf	NA[c]	1.1
Guardian	NA	d

[a] Table 9-12.
[b] Table 9-2.
[c] NA = not available.
[d] Guardian added one small plant in late 1980 that did not contribute significantly to industry capacity.

TABLE 9-27. DEBT TO TOTAL CAPITALIZATION RATIO FOR FOUR PUBLICLY OWNED FIRMS, 1979 TO 1981[6-12]

Year	Company[a]			
	CertainTeed	Guardian Industries	Manville	Owens-Corning
		Long-term debt ($ x 10^6)		
1979	158.8	NA[b]	532.4	192.5
1980	152.1	108.3	519.1	284.2
1981	168.9	124.4	507.6	282.8
Average, 1979 to 1981	159.9	116.4	519.7	253.2
		Total capitalization ($ x 10^6)		
1979	530.4	NA[b]	1,428.8	932.0
1980	507.6	234.8	1,441.0	1,044.0
1981	500.2	282.0	1,410.1	1,056.4
Average, 1979 to 1981	512.7	258.4	1,426.6	1,010.8
		Ratio of long-term debt to capitalization (percent)[c]		
1979	29.9	NA[b]	37.3	20.7
1980	30.0	46.1	36.0	27.2
1981	33.8	44.1	36.0	26.8
Average, 1979 to 1981	31.2	45.0	36.4	25.0

[a] Knauf is a privately owned firm.

[b] Not applicable, because Guardian Industries entered the market in late-1980.

[c] The average weighted capitalization ratio for the four firms, 1979 to 1981, is 32.7 percent.

TABLE 9-28. FINANCIAL STATISTICS FOR FOUR PUBLICLY HELD WOOL FIBERGLASS FIRMS[63-72]

	Moody Rating (10/82)	1981	1980	1979	1978	1977	1976	1975
CertainTeed								
Moody's Commercial Paper Rating	P1[a]	P2	P2	P2	-	-	-	-
Sales ($ x 10^6)		892	868	916	895	818	665	553
Cash flow ($ x 10^6)		43.3	53.5	65.7	82.3	78.5	55.0	35.8
Long term debt ($ x 10^6)		169	152	159	135	133	129	123
Assets ($ x 10^6)		664	694	726	670	611	475	429
Capital spending ($ x 10^6)		29.9	37.0	86.5	145.5	81.4	60.7	30.9
Coverage ratio pre-tax		-	0.90	2.10	8.44	8.78	6.69	5.15
Earnings after tax ($ x 10^6)		(10.9)[b]	0.3	22.2	50.9	54.2	36.6	19.5
Guardian								
Moody's Commercial Paper Rating	P2[a]	-	-	-	-	-	-	-
Sales ($ x 10^6)		330.6	299.1	281.2	200.9	155.6	136.2	106.7
Cash flow ($ x 10^6)		50.8	42.7	34.5	27.8	23.1	18.4	11.9
Long term debt ($ x 10^6)		124.4	108.3	77.2	71.6	43.1	25.3	25.5
Assets ($ x 10^6)		386	318	243	207	143	111	104
Capital spending ($ x 10^6)		67.0	89.5	16.9	54.2	20.0	5.2	5.5
Coverage ratio pre-tax		4.74	7.62	6.91	6.38	16.25	12.90	6.44
Earnings after tax ($ x 10^6)		31.4	28.3	22.7	18.6	15.6	133	7.1
Manville								
Moody's Bond Rating	A3[c,d]	A	A	A	Aa	Aa	Aa	Aa
Sales ($ x 10^6)		2,186	2,227	2,276	1,649	1,461	1,309	1,107
Cash flow ($ x 10^6)		142	160	189	164	141	88	70
Long term debt ($ x 10^6)		508	519	532	543	203	208	186
Assets ($ x 10^6)		2,298	2,338	2,323	2,217	1,334	1,188	1,077
Capital spending ($ x 10^6)		86.1	129.7	189.2	174.0	100.1	73.0	110.0
Coverage ratio pre-tax		2.73	4.40	4.49	11.70	10.53	7.69	4.67
Earnings after tax ($ x 10^6)		60.3	80.6	114.6	121.6	102.6	53.4	38.4

(Continued)

TABLE 9-28, continued

	Moody Rating (10/82)	1981	1980	1979	1978	1977	1976	1975
Owens-Corning								
Moody's Bond Rating	A2[d]	A	A	A	A	A	A	A
Sales ($ x 10^6)		2,375	2,285	2,245	1,853	1,480	1,079	885
Cash flow ($ x 10^6)		168	164	199	193	163	119	86
Long term debt ($ x 10^6)		283	284	193	146	149	155	168
Assets ($ x 10^6)		1,602	1,534	1,502	1,210	1,009	837	750
Capital spending ($ x 10^6)		153.2	176.1	184.5	246.4	99.5	43.8	43.8
Coverage ratio pre-tax		2.70	2.99	9.20	18.89	17.12	10.62	6.37
Earnings after tax ($ x 10^6)		50	54	109	130	113	72	42

[a] Moody's Commercial Paper Rating. P1 is the highest.

[b] Brackets indicate a negative number, or loss.

[c] Bond rating dropped to Ca in September, 1982.

[d] In 1982, A became A2. A1 is slightly higher and A3 is slightly lower than A2.

been over $150 million in each of the last four years which, for comparison purposes is 150 percent of the industry annual capital needs for the entire five year period under Case One. In light of its high bond rating (A2) and pre-tax coverage ratio of 2.70 in this current recession, Owens-Corning should easily be capable of raising the capital necessary to maintain or expand its market share once the recession ends and the projected demand for fiberglass materializes.

CertainTeed's share of market capacity in 1980 was 20.3 percent while 38 percent of its revenues were derived from wool fiberglass sales. Its 33.8 percent ratio of long-term debt to capitalization in 1981 is also reasonably low. Although in the last two years CertainTeed's capital spending has fallen off considerably, this drop is largely due to a fall in sales, earnings, and cash flow which all should recover if the projected demand for wool fiberglass materializes. In a growing market, CertainTeed should be capable of raising the capital needed to maintain its market share.

Until Manville's August 1982, announcement of filing for reorganization under Chapter 11 of the Bankruptcy Act, the company's growth prospects were quite strong. Manville's share of market capacity in 1980 was 15.6 percent while 28 percent of its revenues were derived from the sale of wool fiberglass. Its ratio of long-term debt to capitalization stood at 36.0 percent in 1981, close to the industry average. Even in the 1981 recession year, Manville spent $86.1 million on new investment. Its after-tax earnings, cash flow, and sales are suffering somewhat in this recession, but without Manville's asbestos liabilities the projected fiberglass industry growth by 1988 would be expected to raise Manville's fiberglass sales and profits, leaving it in good position to maintain or expand its capacity share. However, Manville's future expansion plans in the wool fiberglass industry depend critically upon the resolution of the asbestos liability suits against it. Even if Manville is forced out of business because of these suits, in the growing fiberglass industry projected for the period 1983-1988, its plants could be sold to existing firms or new entrants to the industry.

Guardian and Knauf each share less than five percent of the wool fiberglass industry capacity, so analysis of their ability to raise capital for new plant expansion is much less crucial to the question of industry capital availability. Guardian acquired a fiberglass plant in late 1980, and its sales, cash flow, and after-tax earnings all were comparatively strong in 1981, despite the start of the current recession in the industry. Thus, Guardian appears to be in a good position to expand its fiberglass market share when the projected industry demand growth occurs. Kanuf is privately held by a German family, so its ability to expand its fiberglass capacity largely depends upon the assets of that family, which are not known.

In summary, despite the current recession in the industry, if the projected growth in the industry materializes, then all firms in the industry (with the possible exception of Manville) should find reasonable access to new capital, so the abatement capital needed by the industry will be available.

9.2.4 Small Business Impacts

The Regulatory Flexibility Act of 1980 (RFA) requires that differential impacts of federal regulations upon small businesses be identified and analyzed if a substantial number of small businesses will experience significant impacts. The Small Business Administration (SBA) definition of a small business for Standard Industrial Classification (SIC) Code 3296, Mineral Wool, is 750 employees.[73] Table 9-29 shows recent employment levels for each of the four publicly held firms that manufacture wool fiberglass insulation. All of the four firms have more than 750 employees. Therefore, none of the firms meets the SBA definition of a small business and thus no regulatory flexibility analysis is required.

9.2.5 Summary

The impact of the regulatory alternatives on prices, return on investment, and capital availability have been examined. On all grounds, the regulatory alternatives for the rotary spin process are readily affordable. The maximum price increases to the consumer are small (the largest is 0.5 percent at an 86 percent capacity utilization rate). It is unlikely that the alternative to maximum price increases, namely, full cost absorption, will occur because the industry is an oligopoly. Even if firms absorb the entire abatement cost, the ROI impacts will be small. In addition, firms in this industry have reasonable access to new capital, so the abatement investment costs can be raised.

TABLE 9-29. NUMBER OF EMPLOYEES FOR THE FOUR PUBLICLY HELD WOOL FIBERGLASS FIRMS[74-77]

Firm[a]	No. of employees
CertainTeed Corporation	8,400
Guardian Industries, Inc.	3,800
Manville Corporation	27,000
Owens-Corning Fiberglas Corporation	21,800

[a] Knauf is a privately held, large German firm with too many employees to qualify as a small business.

9.3 POTENTIAL SOCIOECONOMIC AND INFLATIONARY IMPACTS

The purpose of Section 9.3 is to address macroeconomic impacts to determine whether a detailed regulatory analysis is required under Executive Order 12291. There are three principal review criteria to aid in this determination.

1. If additional annualized costs of compliance, including capital charges (interest and depreciation), total $100 million (i) within any one of the first 5 years of implementation, or (ii) if applicable, within any calendar year up to the date by which the law requires attainment of the relevant pollution standard;

2. If a major increase in the selling price of the product results for consumers, individual industries, Federal, State or local government agencies, or geographic regions; or

3. If significant adverse effects on competition, investment, productivity, employment, innovation, or the ability of U.S. firms to compete with foreign firms results.

9.3.1 Fifth-Year Annualized Costs

Table 9-30 summarizes the fifth-year annualized costs of compliance by model plant and line size for the four regulatory alternatives that are the most cost effective. The fifth-year annualized costs vary from a low of $2,597,000 to a maximum of $4,851,000.

The sum of projected fifth-year annualized costs is, therefore, well below the $100 million which, according to Executive Order 12291, signifies a major regulation.

9.3.2 Inflationary Impacts

The small share of wool fiberglass insulation in gross national product in conjunction with the low maximum price increases of at most 0.5 percent (at 86 percent capacity utilization) reported in Section 9.2.1 ensures that the imposition of the regulatory alternative will cause an insignificant increase in the rate of inflation.

9.3.3 Output Effects

The effects on the output of wool fiberglass of the 0.5 percent maximum price increase can be calculated using the demand equation in Appendix E.

First, take the base case forecast. Assuming the entire maximum price increase of 0.5 percent is passed on to the consumer by 1987, prices

TABLE 9-30. FIFTH-YEAR (1988) ANNUALIZED COSTS OF COMPLIANCE FOR ROTARY SPIN MODEL PLANTS AND LINES[78, 79]

Alternative Model Plant and Line Size[a]	Regulatory Alternative	Control Equipment[b]	Total fifth-year annualized costs above the baseline[c,bc] ($000)
All medium model plants and medium model line	III[d]	Scrub., Scrub.[f]	2,863
		ESP, ESP[g]	3,148
	IV[e]	ESP,ESP,ESP	4,154
		Scrub., Scrub., Scrub.	3,990
All small model plants and small model lines	III	Scrub., Scrub.	2,597
		ESP, ESP	3,185
	IV	ESP,ESP,ESP	4,704
		Scrub., Scrub., Scrub	4,851

[a] Growth projections assume 3 new plants and 17 new lines between 1983 and 1988.

[b] Baseline 1988 annualized costs for medium plants and lines equals $19,511,000. Baseline 1988 annualized costs for small plants and line equals $15,360,000.

[c] January 1982 dollars.

[d] Requires control of emissions from the forming and curing sections.

[e] Requires control of emissions from the forming, curing and cooling sections.

[f] Scrub. = Scrubber.

[g] ESP = Wet Electrostatic Precipitator.

will rise 5.3 percent instead of 4.8 percent in 1987. This results in a 1987 level of output of 1,806.3 Gg (3,978.6 x 10^6 lb) instead of 1,811.5 Gg (3,990.1 x 10^6 lb), a decrease of 5.2 Gg (11.5 x 10^6 lb), or 0.3 percent from what output would have been in the absence of regulation.

The implications of a 0.5 percent maximum price increase have also been calculated for the alternative to the base case. In that situation, prices in 1987 would rise 9.9 percent instead of the 9.4 percent forecast without regulation. As a result, output in 1987 would be 1,599.9 Gg (3,524.0 x 10^6 lb) instead of 1,604.0 Gg (3,533.0 x 10^6 lb), a decrease of 4.1 Gg (9.0 x 10^6 lb), or 0.3 percent from what output would have been in the absence of regulation.

9.3.4 Employment Effects

The effect of the regulatory alternatives on employment in the wool fiberglass industry is also small because output is reduced by only 0.3 percent. Assuming a fixed labor-output ratio between 1979 and 1987, total employment without any regulation would be 21,106 in 1987. Under Regulatory Alternative III, it is forecast to be 21,046, or a reduction of 60 employees or 0.3 percent from what employment would have been in the absence of any regulation.

9.3.5 Other Impacts

No major impacts are expected on geographical regions, local governments, competition, investment or productivity. Therefore, no significant macroeconomic impacts are likely.

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APPENDIX A.

EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

In the Federal Register of August 21, 1979, fiberglass manufacturing was major source category number 42 on the Priority List for development of new source performance standards. A screening study was initiated in November 1979 which led to the decision to develop a Background Information Document (BID) on wool fiberglass insulation manufacturing.

In August 1980, an effort was begun to obtain the information needed to develop the BID. The information gathering included literature surveys; canvassing of State, regional, and local air pollution control agencies; plant visits; meetings with industry representatives; contact with engineering consultants and equipment vendors; and emission source testing. Significant events relating to the evolution of the BID are itemized in Table A-1.

TABLE A-1. EVOLUTION OF THE BACKGROUND INFORMATION DOCUMENT

Date	Company, consultant, or agency/location	Nature of action
01/07/80	CertainTeed Corp. Berlin, N.J.	Plant visit
01/08/80	Johns-Manville Sales Corp. Berlin, N.J.	Plant visit
01/09/80	Owens-Corning Fiberglas Corp. Barrington, N.J.	Plant visit
01/10/80	CertainTeed Corp. Chowchilla, Calif.	Plant visit
01/14/80	Owens-Corning Fiberglas Corp. Newark, Ohio	Plant visit
01/15/80	Knauf Fiber Glass GmbH Shelbyville Ind.	Plant visit
01/16/80	Owens-Corning Fiberglas Corp. Anderson, S.C.	Plant visit
04/09/80	PPG Industries, Inc. Lexington, N.C.	Plant visit
06/04/80	Midwest Research Institute Raleigh, N.C.	Project start date for new contractor
06/09/80	Pacific Environmental Sciences, Inc. Durham, N.C.	"Draft Phase I Source Category Survey Report--Fiberglass Manufacturing"
08/06/80	Knauf Fiber Glass GmbH Shelbyville, Ind.	Plant visit
08/28/80	Midwest Research Institute Raleigh, N.C.	"Development of New Source Performance Standards--Interim Phase--for Fiberglass Manufacturing"
09/09/80	Reichhold Chemicals, Inc. Bremen, Ohio	Plant visit
09/24/80	CertainTeed Corp. Mountain Top, Pa.	Plant visit
10/06/80	U.S. EPA, Midwest Research Institute, Engineering Science, Knauf Fiber Glass GmbH, CertainTeed Corp., Owens-Corning Fiberglas Corp. Durham, N.C.	Meeting to discuss standard development

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
10/07/80	Owens-Corning Fiberglas Corp. Newark, Ohio	Plant visit
10/15/80	Johns-Manville Sales Corp. Winder, Ga.	Plant visit
10/30/80	Plant/line A, G, H	Pretest survey
12/21/80	Plant/line K	Pretest survey
12/31/80	Knauf Fiber Glass GmbH Shelbyville, Ind. Johns-Manville Sales Corp. Denver, Colo. CertainTeed Corp. Blue Bell, Pa.	Section 114 information request
01/04/81	Plant/line B, C, E	Pretest survey
01/07/81	Owens-Corning Fiberglas Corp. Toledo, Ohio	Section 114 information request
01/07/81	Plant/line I, J	Pretest survey
01/28/81	Plant/line D	Pretest survey
02/04/81	CertainTeed Corp. Chowchilla, Calif.	Plant visit
04/06/81-04/14/81	Plant/line D	Emission test
04/30/81	CertainTeed Corp. Blue Bell, Pa.	Follow up to Section 114 information request
05/27/81-06/01/81	Plant/line G, H, K	Emission test
07/07/81-07/16/81	Plant/line F, I, J	Emission test
08/25/81-08/27/81 and 09/08/81-09/11/81	Plant/line C, E	Emission test

(continued)

TABLE A-1. (continued)

Date	Company, consultant, or agency/location	Nature of action
09/22/81-09/24/81 and 10/17/81-10/19/81	Plant/line A	Emission test
12/07/81-12/11/81	Plant/line B	Emission test
02/23/82	MikroPul Corp. (Summit, N.J.), U.S. EPA, Midwest Research Institute	Meeting to discuss control technology
03/12/82	CertainTeed Corp. Blue Bell, Pa. Knauf Fiber Glass GmbH Shelbyville, Ind.	Follow up to Section 114 information requests
04/01/82	United McGill Corp. (Columbus, Ohio), U.S. EPA, Midwest Research Institute	Meeting to discuss control technology
04/01/82	Andersen 2000, Inc. Atlanta, Ga.	Information request letter
04/14/82	CertainTeed Corp. Athens, Ga.	Plant visit
09/15/82	CertainTeed Corp. Blue Bell, Pa. Guardian Industries Corp. Northville, Mich. Knauf Fiber Glass GmbH Shelbyville, Ind. Manville Corp. Denver, Colo. Owens-Corning Fiberglas Corp. Toledo, Ohio	Draft BID chapter mailout
09/27/82-09/29/82	Plant/line L	Emission test

APPENDIX B

INDEX TO ENVIRONMENTAL IMPACT CONSIDERATIONS

This appendix consists of a reference system, cross-indexed with the October 21, 1974, Federal Register (39 FR 37419) containing the Agency guidelines concerning the preparation of environmental impact statements. This index can be used to identify sections of the document which contain data and information germane to any portion of the Federal Register guidelines.

TABLE B-1. CROSS-INDEXED REFERENCE SYSTEM TO HIGHLIGHT ENVIRONMENTAL IMPACT PORTIONS OF THE DOCUMENT

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within the Background Information Document
1. BACKGROUND AND SUMMARY OF REGULATORY ALTERNATIVES	
Summary of regulatory alternatives	The regulatory alternatives from which standards will be chosen for proposal are summarized in Chapter 1, Section 1.1.
Statutory basis for proposing standards	The statutory basis for proposing standards is summarized in Chapter 2, Section 2.1.
Relationship to other regulatory agency actions	The relationships between EPA and other regulatory agency actions are discussed in Chapters 3 and 8.
Industry affected by the regulatory alternatives	A discussion of the industry affected by the regulatory alternatives is presented in Chapter 3, Section 3.1. Further details covering the business and economic nature of the industry are presented in Chapter 9, Section 9.1.
Specific processes affected by the regulatory alternatives	The specific processes and facilities affected by the regulatory alternatives are summarized in Chapter 1, Section 1.1. A detailed technical discussion of the processes affected by the regulatory alternatives is presented in Chapter 3, Section 3.2.
2. REGULATORY ALTERNATIVES	
Control techniques	The alternative control techniques are discussed in Chapter 4, Sections 4.1, 4.2, 4.3, 4.4, and 4.5.

(continued)

TABLE B-1 (continued)

Agency guidelines for preparing regulatory action environmental impact statements (39 FR 37419)	Location within the Background Information Document
Regulatory alternatives	The various regulatory alternatives, including "no additional regulatory action," are defined in Chapter 6, Section 6.4. A summary of the major alternatives considered is included in Chapter 1, Section 1.1.
3. ENVIRONMENTAL IMPACT OF THE REGULATORY ALTERNATIVES	
Primary impacts directly attributable to the regulatory alternatives	The primary impacts on mass emissions and ambient air quality due to the alternative control systems are discussed in Chapter 7, Sections 7.1, 7.2, 7.3, 7.4, and 7.5. A matrix summarizing the environmental impacts is included in Chapter 1.
Secondary or induced impacts	Secondary impacts for the various regulatory alternatives are discussed in Chapter 7, Sections 7.1, 7.2, 7.3, 7.4, and 7.5.
4. OTHER CONSIDERATIONS	A summary of the potential adverse environmental impacts associated with the regulatory alternatives is included in Chapter 1, Section 1.2, and Chapter 7. Potential socio-economic and inflationary impacts are discussed in Chapter 9, Section 9.2. Irreversible and irretrievable commitments of resources are discussed in Chapter 7, Section 7.6.

APPENDIX C. SUMMARY OF EMISSION TEST DATA FOR WOOL FIBERGLASS INSULATION MANUFACTURING

C.1 INTRODUCTION

This appendix presents the emission test data obtained from wool fiberglass insulation manufacturing plants. Nine RS and three FA lines were tested during the sampling program. Pollutants measured during all tests include particulate matter, phenol, phenolic compounds, and formaldehyde. In addition, the opacity of visible emissions was recorded during 11 of the tests.

The particulate emission data were obtained using a modified EPA Reference Method 5. A spectrophotometric method was used for analysis of the phenolic compounds and formaldehyde and a gas chromatographic method was used to analyze the phenol. The visible emissions data were obtained using Reference Method 9.

C.2 EMISSION TEST DATA

The following subsections present a brief description of each line tested, a summary of the emission data obtained from that line and any corresponding process parameters, and a discussion of the data excluded from that line.

All controlled emissions data are summarized by pollutant in subsection C.2.13. The visible emissions data are summarized in subsection C.2.14.

C.2.1 Line A

The emission sources tested for line A are shown in the schematic diagram in Figure C-1. Three emission tests were performed on line A because three types of fiberglass insulation are produced on this line: R-11 building insulation, R-19 building insulation, and ductboard.

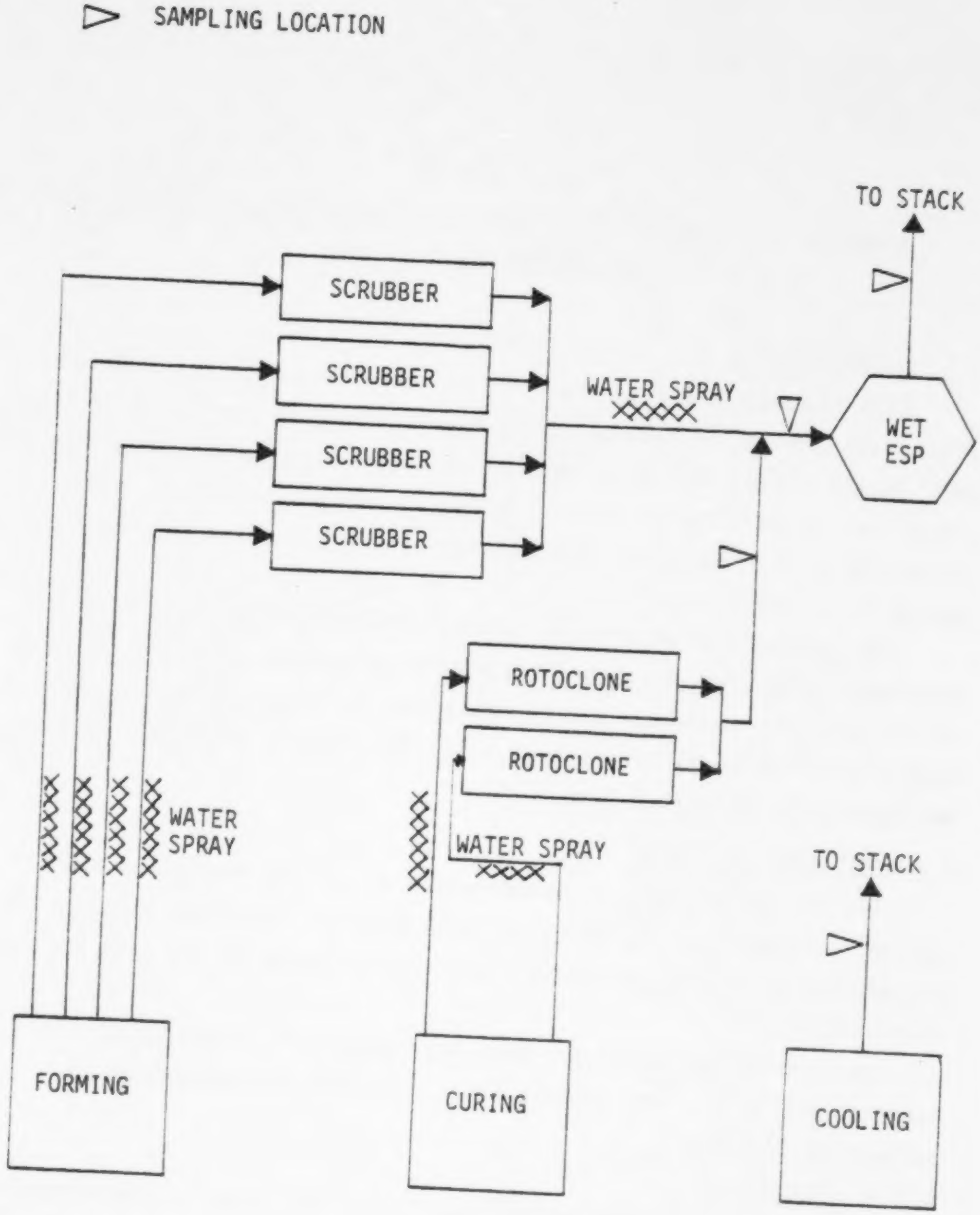

▷ SAMPLING LOCATION
TO STACK
SCRUBBER
SCRUBBER
SCRUBBER
SCRUBBER
WATER SPRAY
WET ESP
ROTOCLONE
ROTOCLONE
WATER SPRAY
WATER SPRAY
TO STACK
FORMING
CURING
COOLING

Figure C-1. Schematic drawing of sampling locations for Line A.

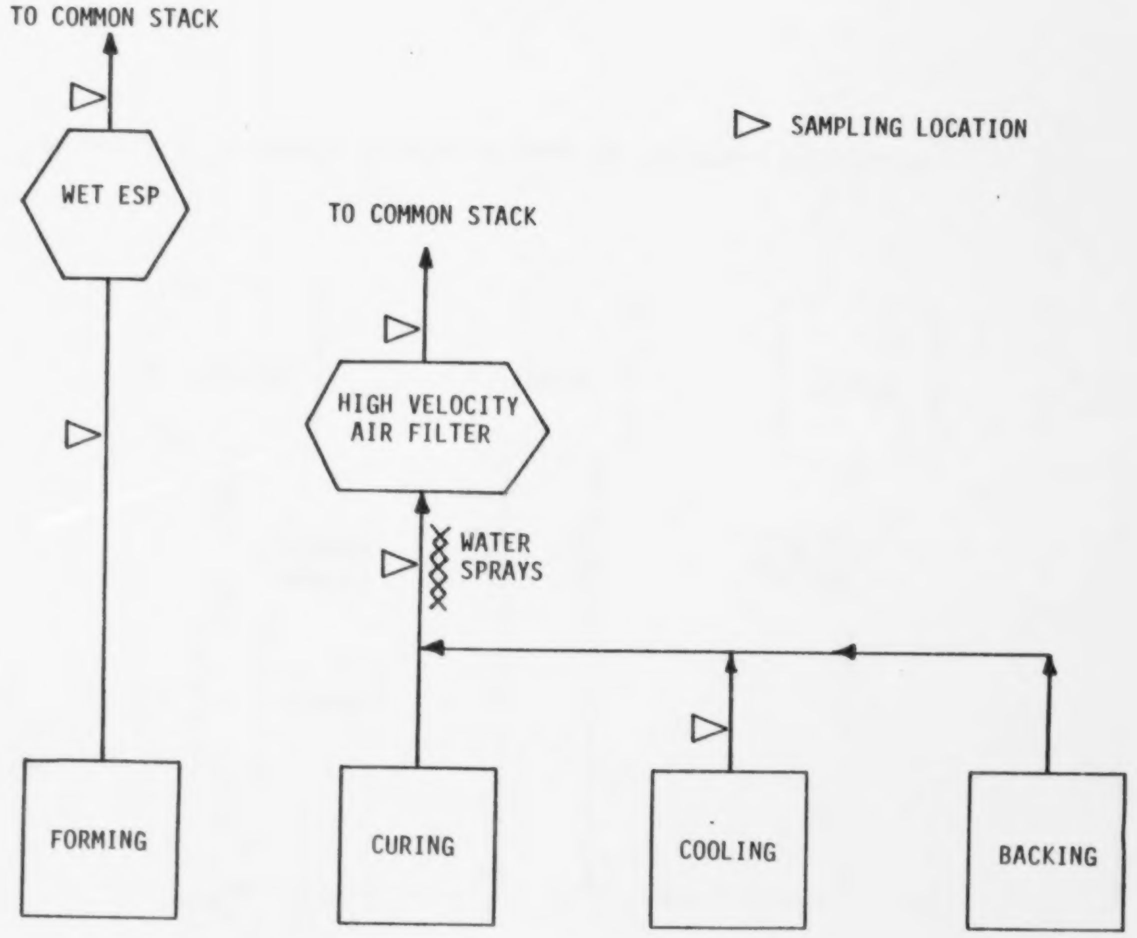
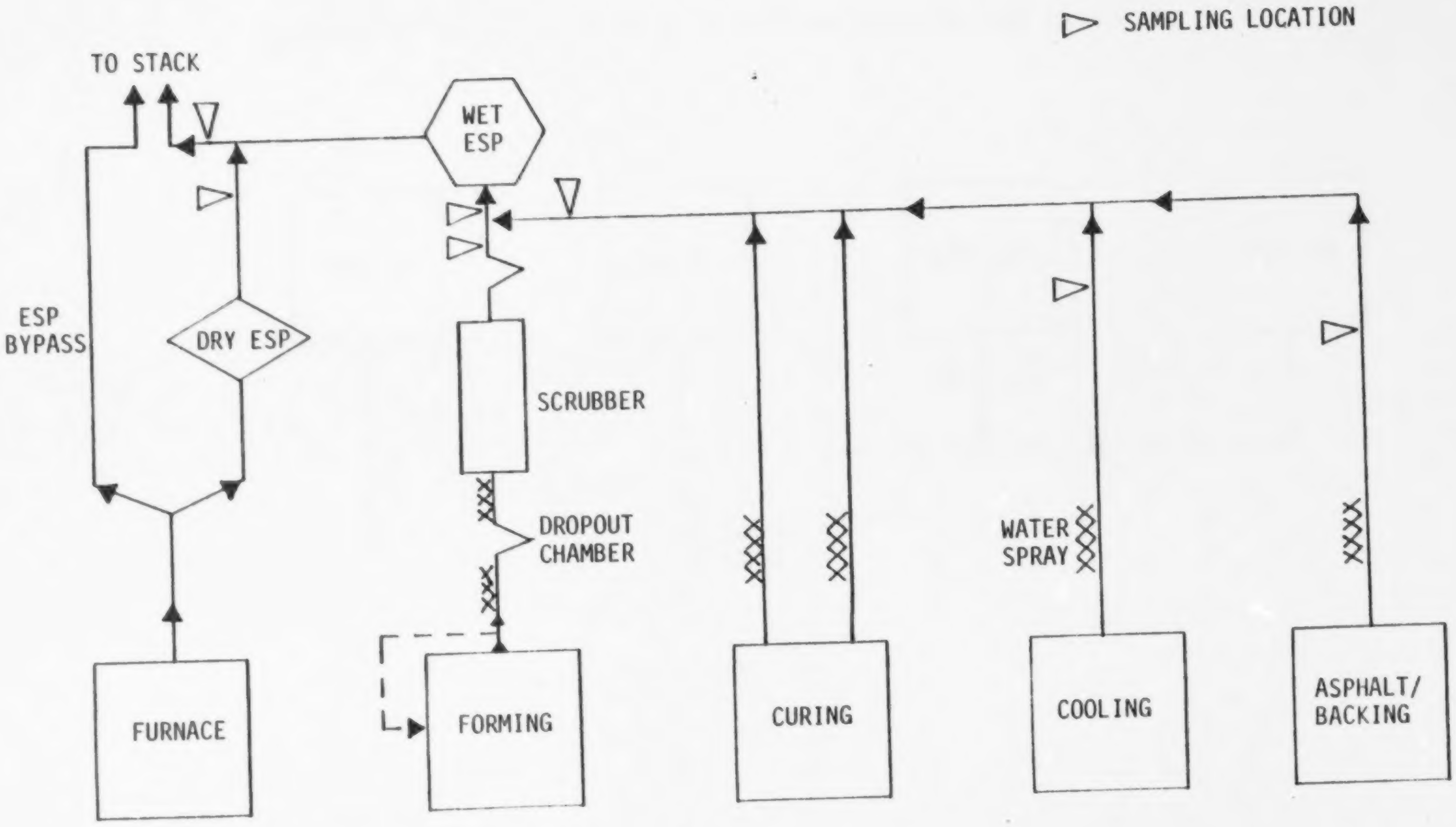

TO COMMON STACK
WET ESP
TO COMMON STACK
HIGH VELOCITY AIR FILTER
WATER SPRAYS
▷ SAMPLING LOCATION
FORMING
CURING
COOLING
BACKING

Figure C-3. Schematic drawing of sampling locations for Line C.



SAMPLING LOCATION
TO STACK
WET ESP
ESP BYPASS
DRY ESP
SCRUBBER
DROPOUT CHAMBER
WATER SPRAY
FURNACE
FORMING
CURING
COOLING
ASPHALT/ BACKING

Figure C-4. ´Schematic drawing of sampling locations for Line D.

(nonisokinetic conditions, no back half analyses, broken sampling train, failed leak check) and/or process condition deficiencies (wet ESP drain malfunctions). The excluded data are indicated on the data summary sheets.

C.2.5 Line E

The emission sources tested for line E are shown in Figure C-5. The emission test results are presented in Tables C-31a to C-36b. During the three tests performed on the wet ESP on line E, the unit was operating between 137 and 154 percent of design inlet air flow; therefore, all of these data were excluded from the data base.

C.2.6 Line F

The emission sources tested for line F are shown in the schematic diagram in Figure C-6. The emission test results are presented in Tables C-37a to C-41b. The emission data obtained from the curing north location (run 2) were excluded from the data base because the isokinetic sampling rate was 151.3 percent. Line F is uncontrolled.

C.2.7 Line G

Figure C-7 shows a schematic diagram of the sampling locations for line G. The emission test results are presented in Tables C-42a and C-42b. Line G is uncontrolled.

C.2.8 Line H

Figure C-7 shows the emission sources for line H. The emission test results are presented in Tables C-43a and C-43b. Line H is uncontrolled.

C.2.9 Line I

The emission sources tested for line I, an FA process, are shown in Figure C-8. Tables C-44a to C-49b present the emission test results from line I. The HVAF inlet gas flow rate was not measureable. The HVAF outlet data for runs 2, 3, and 4 were excluded because the data were obtained while water sprays were operating, which is not a normal plant operating condition.

C.2.10 Line J

The emission sources tested for line J, an FA process, are shown in Figure C-9. The emission test results are presented in Tables C-50a to C-57b. The HVAF inlet gas flow rate was 69 percent of the design flow

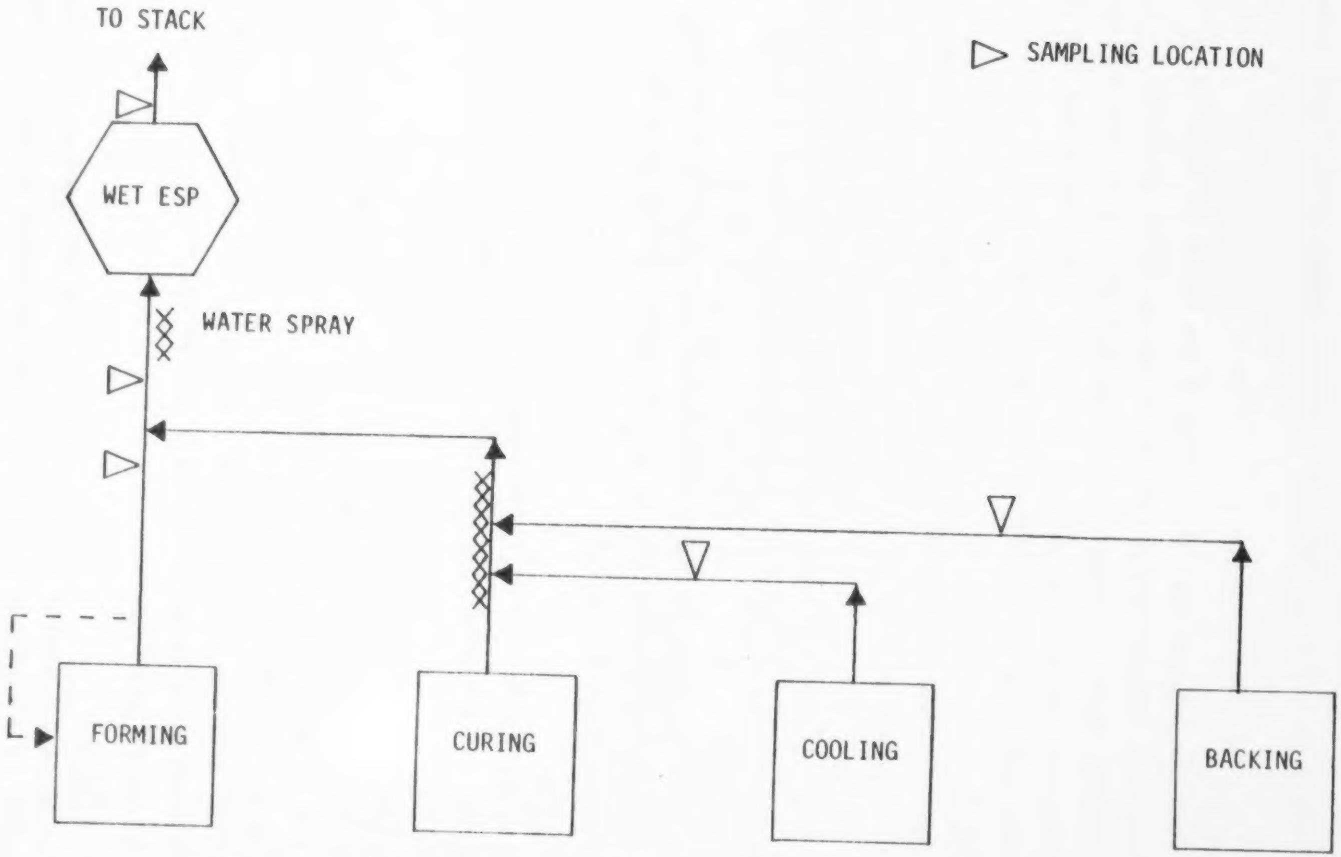

TO STACK
▷ SAMPLING LOCATION
WET ESP
WATER SPRAY
FORMING
CURING
COOLING
BACKING

Figure C-5. Schematic drawing of sampling locations for Line E.

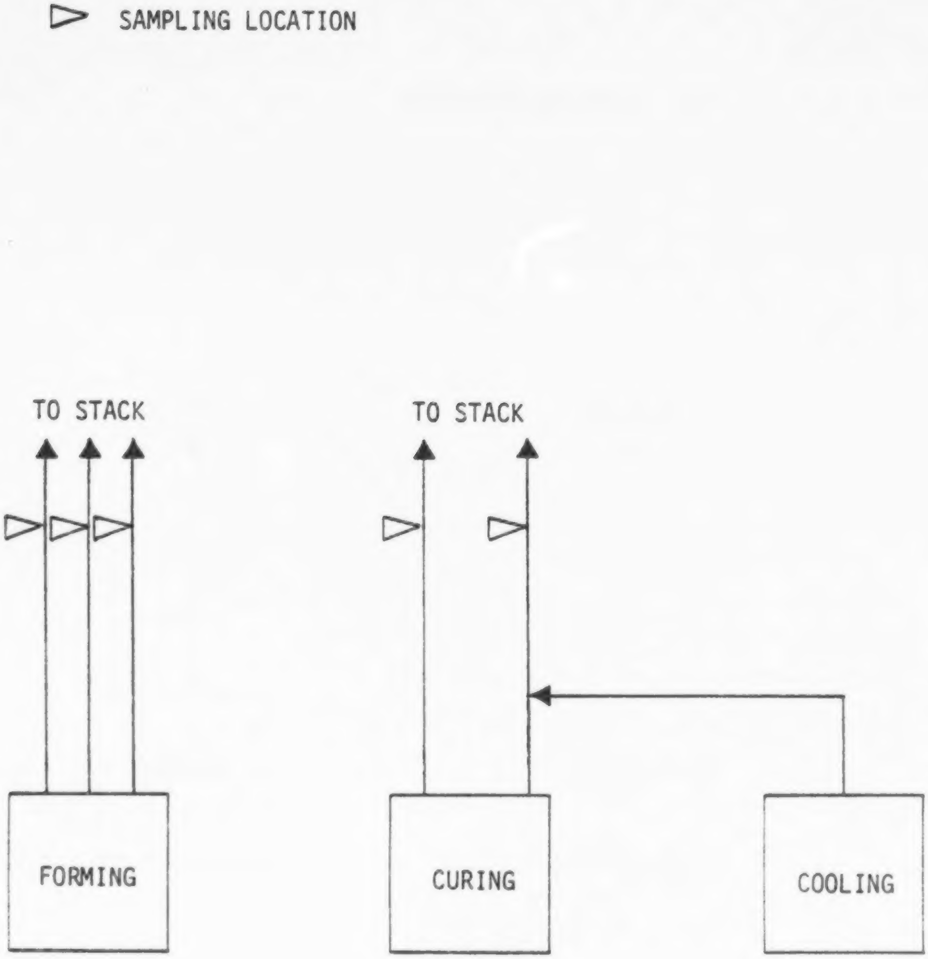

SAMPLING LOCATION
TO STACK
TO STACK
FORMING
CURING
COOLING

Figure C-6. Schematic drawing of sampling locations for Line F.

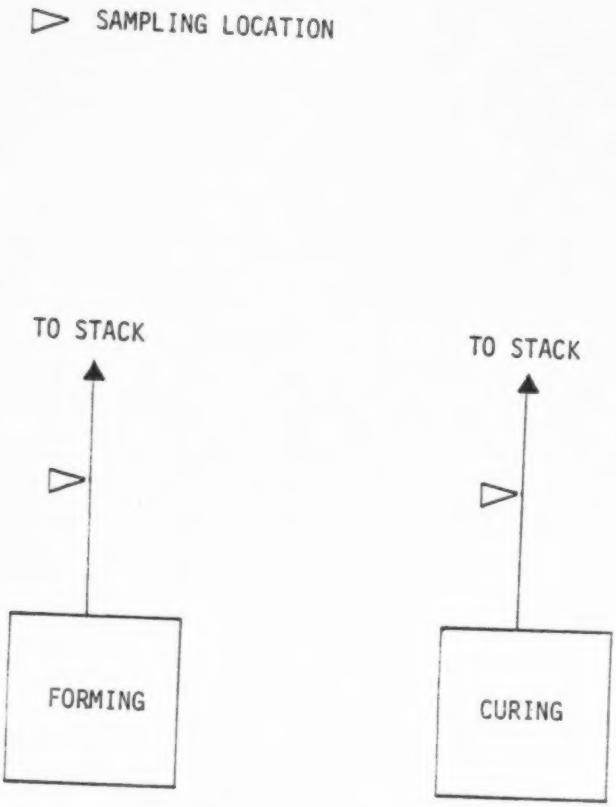

SAMPLING LOCATION
TO STACK
TO STACK
FORMING
CURING

Figure C-7. Schematic drawing of sampling locations for Lines G and H.

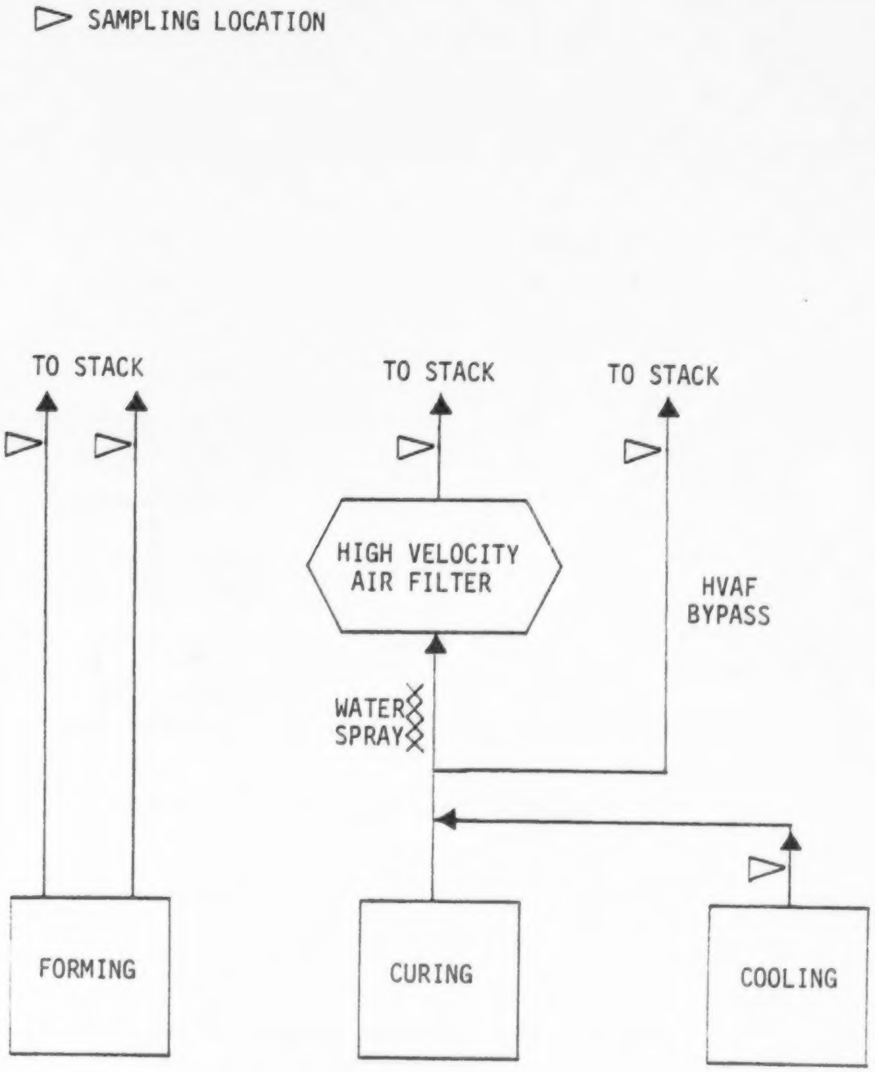

SAMPLING LOCATION
TO STACK
TO STACK
TO STACK
HIGH VELOCITY AIR FILTER
HVAF BYPASS
WATER SPRAY
FORMING
CURING
COOLING

Figure C-8. Schematic drawing of sampling locations for Line I.

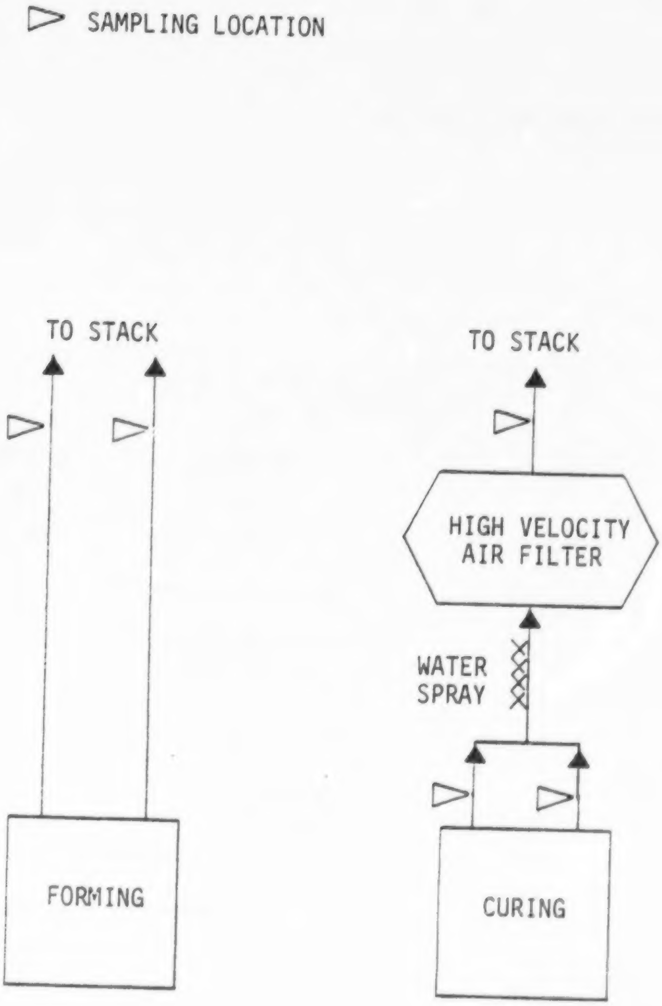

SAMPLING LOCATION
TO STACK
TO STACK
HIGH VELOCITY AIR FILTER
WATER SPRAY
FORMING
CURING

Figure C-9. Schematic drawing of sampling locations for Line J.

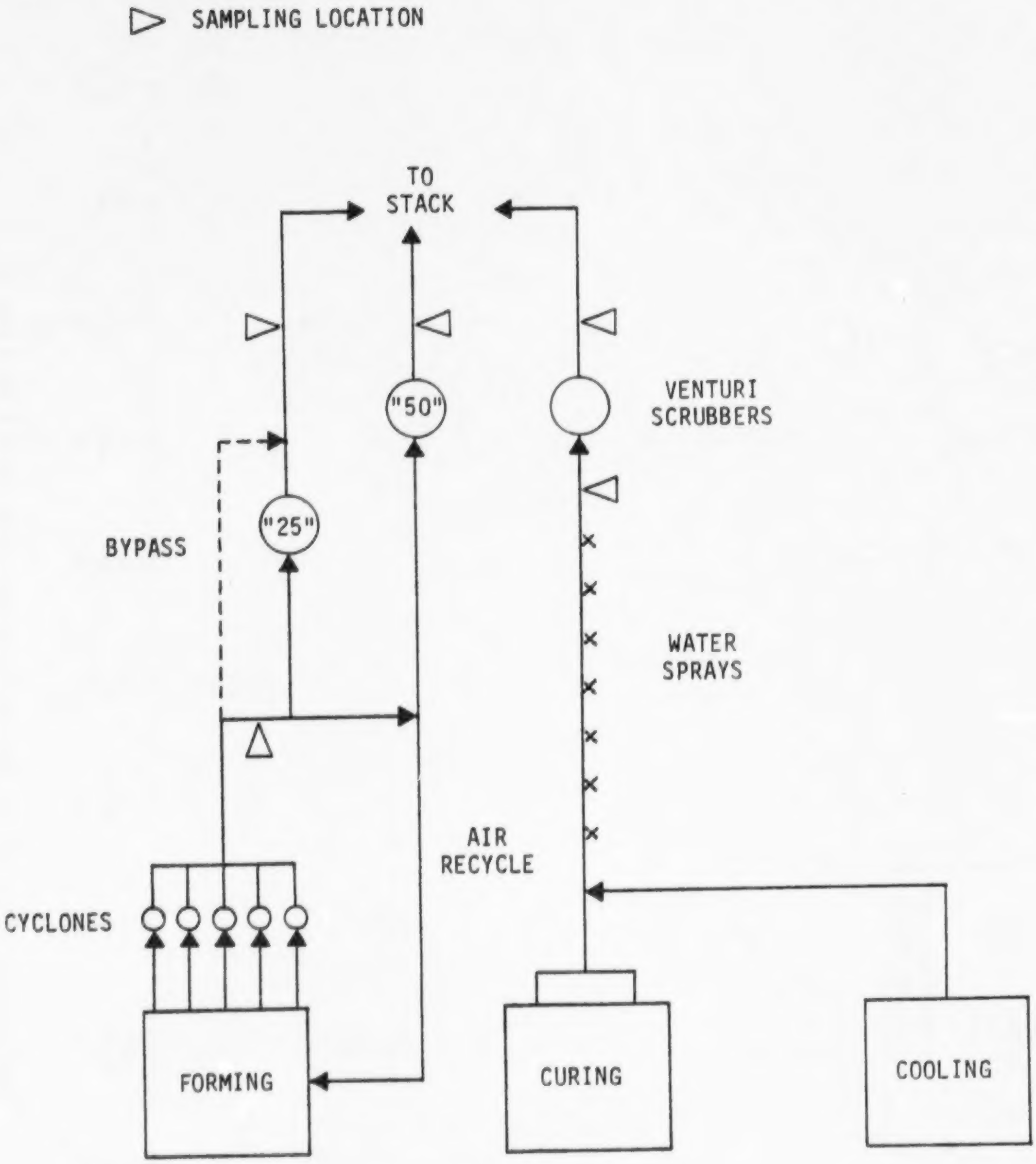

▷ SAMPLING LOCATION
TO STACK
"50"
"25"
VENTURI SCRUBBERS
BYPASS
WATER SPRAYS
AIR RECYCLE
CYCLONES
FORMING
CURING
COOLING

Figure C-11. Schematic drawing of sampling locations for Line L.

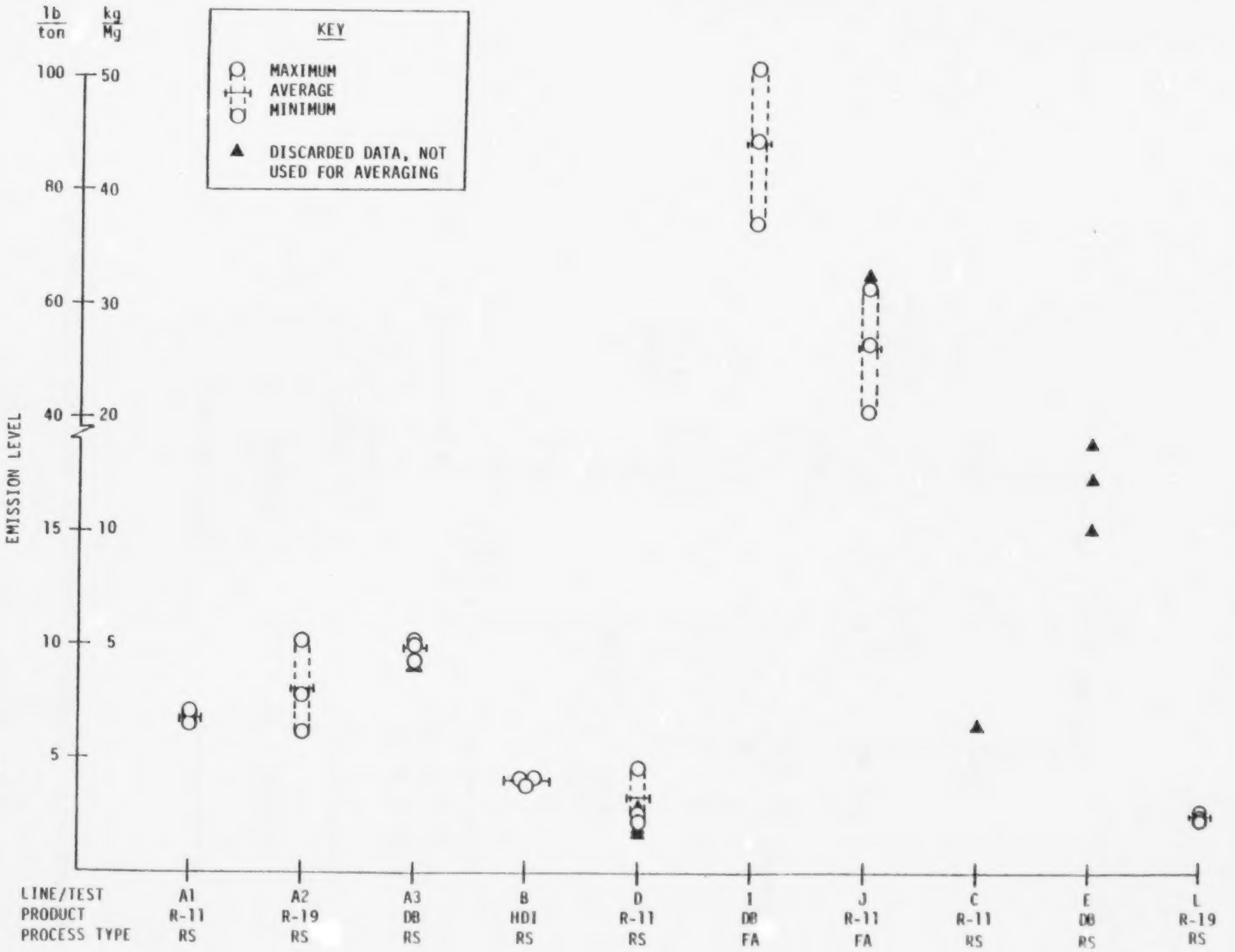


Figure C-12. Controlled particulate emission levels by line for wool fiberglass manufacturing, including discarded data.

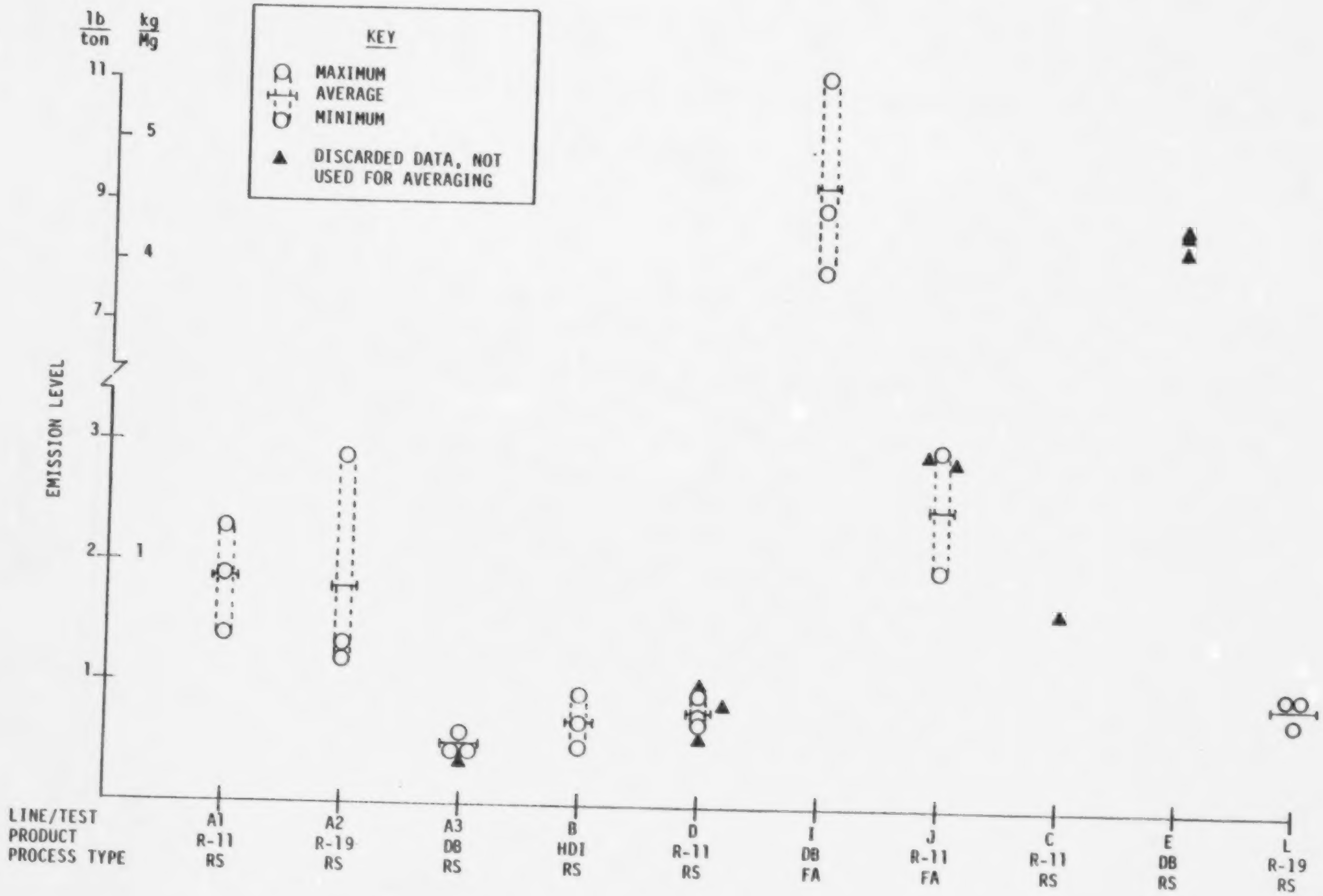


Figure C-13. Controlled phenol emission levels by line for wool fiberglass manufacturing, including discarded data.

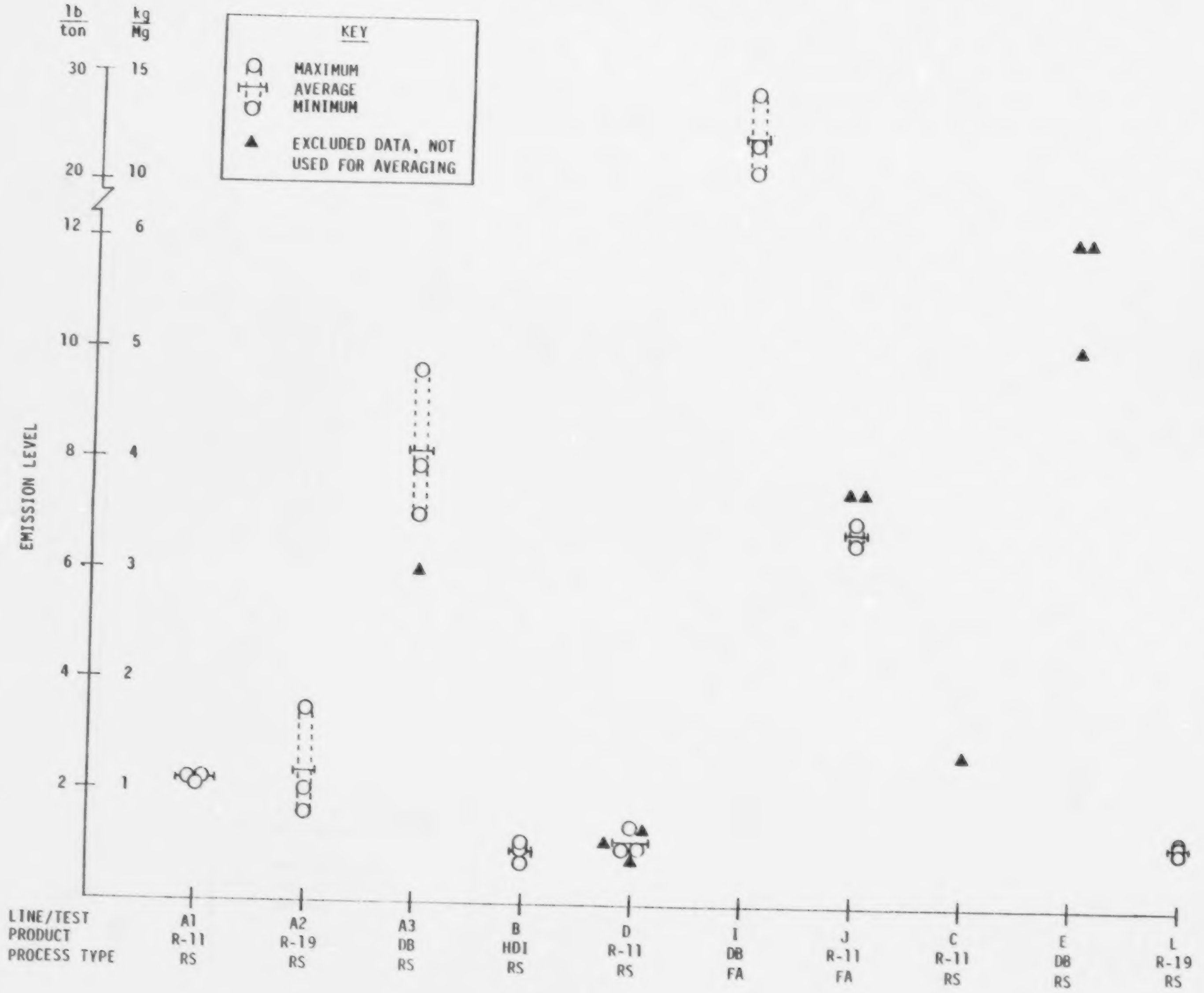


Figure C-14. Controlled phenolic compounds emission levels by line for wool fiberglass manufacturing, including discarded data.

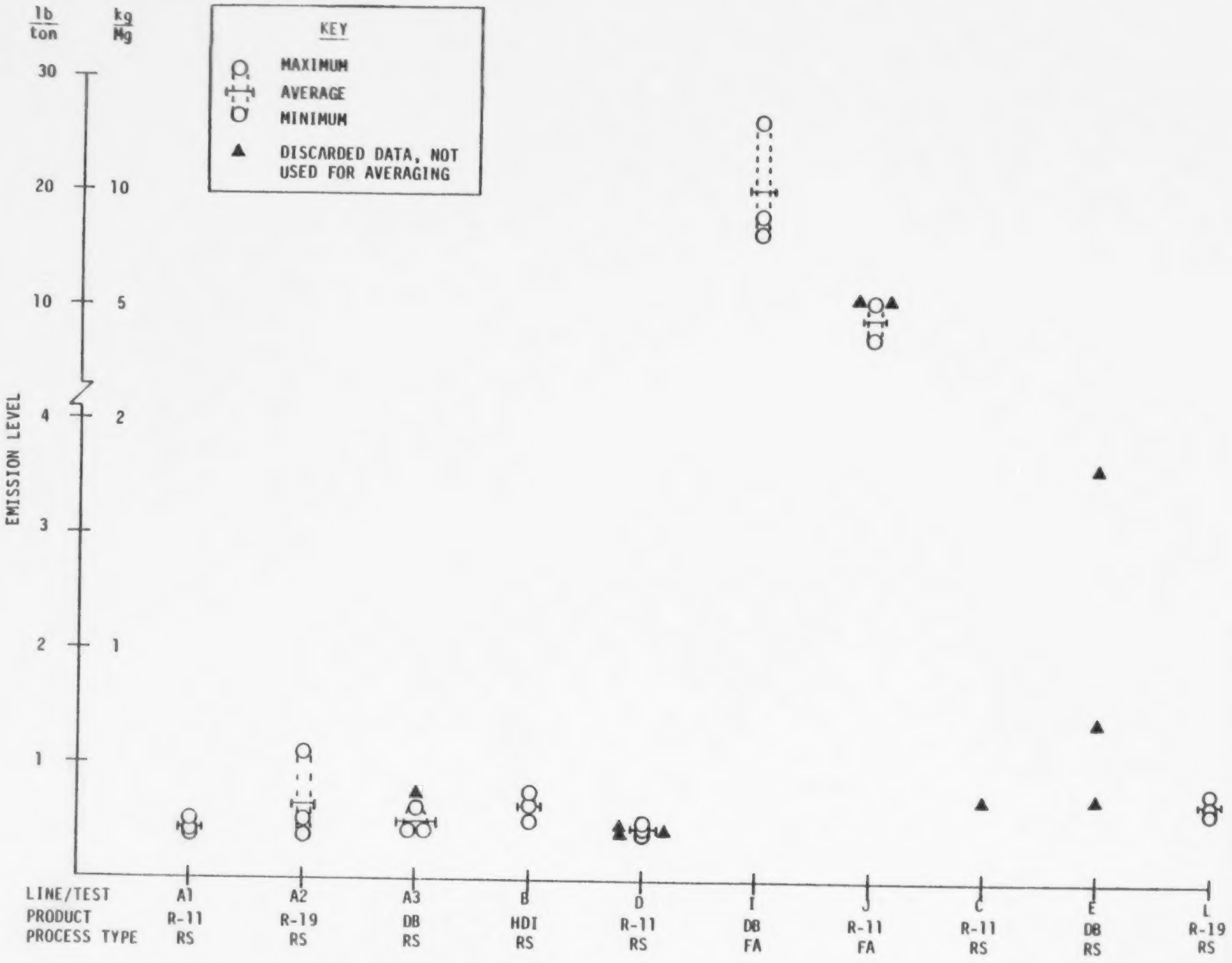


Figure C-15. Controlled formaldehyde emission levels by line for wool fiberglass manufacturing, including discarded data.

C.2.14 Visible Emission Data

The visible emission data from the test program are summarized and presented in Tables C-69 to C-165.

TABLE C-1a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Inlet
Product: R-11 Building Insulation
(English)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	96	96	96	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	4.94	4.60	5.18	4.91
Avg. stack temperature, °F	90.9	88.7	92.7	90.8
Isokinetic, %	95.7	94.3	97.0	95.667
Volume of gas sampled, dscf	76.066	71.674	72.968	73.693
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	20.733	22.938	8.448	17.373
Concentration, gr/dscf	0.273	0.320	0.116	0.236
Emission level, lb/ton	156.44	140.86	49.42	115.57
Phenolic compounds				
Mass collected, gr	4.829	5.496	3.972	4.766
Concentration, gr/dscf	0.064	0.077	0.054	0.065
Emission level, lb/ton	36.44	33.75	23.27	31.15
Phenol				
Mass collected, gr	0.471	0.598	0.419	0.496
Concentration, gr/dscf	0.006	0.008	0.006	0.007
Emission level, lb/ton	3.56	3.67	2.46	3.23
Formaldehyde				
Mass collected, gr	0.944	0.408	0.330	0.561
Concentration, gr/dscf	0.012	0.006	0.005	0.008
Emission level, lb/ton	7.12	2.51	1.93	3.85

N/A = Not applicable.

TABLE C-1b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Inlet
Product: R-11 Building Insulation
(Metric)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	96	96	96	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	4.94	4.60	5.18	4.91
Avg. stack temperture, °C	32.7	31.5	33.7	32.6
Isokinetic, %	95.7	94.3	97.0	95.7
Volume of gas sampled, Nm^3	2.154	2.030	2.066	2.083
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	1,346.30	1,489.50	548.60	1,128.13
Concentration, mg/Nm^3	623.72	732.36	264.95	540.34
Emission level, kg/Mg	78.22	70.43	24.71	57.79
Phenolic compounds				
Mass collected, mg	313.60	356.90	257.90	309.47
Concentration, mg/Nm^3	145.29	175.48	124.56	148.441
Emission level, kg/Mg	18.22	16.88	11.64	15.58
Phenol				
Mass collected, mg	30.60	38.80	27.20	32.20
Concentration, mg/Nm^3	14.18	19.08	13.14	15.46
Emission level, kg/Mg	1.78	1.84	1.23	1.62
Formaldehyde				
Mass collected, mg	61.30	26.50	21.40	36.40
Concentration, mg/Nm^3	28.40	13.03	10.34	17.26
Emission level, kg/Mg	3.56	1.26	0.97	1.93

N/A = Not applicable.

TABLE C-2a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Outlet
Product: R-11 Building Insulation
(English)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	108	108	108	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	3.79	5.41	6.15	5.12
Avg. stack temperature, °F	82.6	97.3	98.0	92.6
Isokinetic, %	96.9	98.6	98.9	98.1
Volume of gas sampled, dscf	46.591	46.400	49.085	47.359
Opacity average, %	10	9	9	--
Particulate matter				
Mass collected, gr	0.573	0.681	0.738	0.664
Concentration, gr/dscf	0.012	0.015	0.015	0.014
Emission level, lb/ton	6.68	6.25	6.63	6.52
Phenolic compounds				
Mass collected, gr	0.188	0.231	0.242	0.220
Concentration, gr/dscf	0.004	0.005	0.005	0.005
Emission level, lb/ton	2.19	2.12	2.17	2.16
Phenol				
Mass collected, gr	0.120	0.249	0.213	0.194
Concentration, gr/dscf	0.003	0.005	0.004	0.004
Emission level, lb/ton	1.40	2.29	1.91	1.87
Formaldehyde				
Mass collected, gr	0.043	0.039	0.045	0.042
Concentration, gr/dscf	0.001	0.001	0.001	0.004
Emission level, lb/ton	0.50	0.35	0.40	0.42

TABLE C-2b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Outlet
Product: R-11 Building Insulation
(Metric)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	108	108	108	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	3.79	5.41	6.15	5.12
Avg. stack temperture, °C	28.1	36.3	36.7	33.70
Isokinetic, %	96.9	98.6	98.9	98.1
Volume of gas sampled, Nm^3	1.319	1.314	1.390	1.341
Opacity average, %	10	9	9	--
Particulate matter				
Mass collected, mg	37.20	44.20	47.90	43.10
Concentration, mg/Nm^3	28.14	33.57	34.39	32.03
Emission level, kg/Mg	3.34	3.13	3.32	3.26
Phenolic compounds				
Mass collected, mg	12.20	15.00	15.70	14.30
Concentration, mg/Nm^3	9.23	11.39	11.27	10.63
Emission level, kg/Mg	1.10	1.06	1.09	1.08
Phenol				
Mass collected, mg	7.80	16.20	13.80	12.60
Concentration, mg/Nm^3	5.90	12.30	9.91	9.37
Emission level, kg/Mg	0.70	1.15	0.96	0.94
Formaldehyde				
Mass collected, mg	2.80	2.50	2.90	2.73
Concentration, mg/Nm^3	2.12	1.90	2.08	2.03
Emission level, kg/Mg	0.25	0.18	0.20	0.21

TABLE C-3a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Rotoclone
Product: R-11 Building Insulation
(English)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	88	88	88	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	3.70	4.54	4.42	4.22
Avg. stack temperature, °F	120.50	121.50	120.50	120.83
Isokinetic, %	99.8	100.0	100.9	100.2
Volume of gas sampled, dscf	79.066	75.084	77.446	77.199
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	2.681	2.718	2.293	2.564
Concentration, gr/dscf	0.034	0.036	0.038	0.036
Emission level, lb/ton	4.99	4.05	4.23	4.42
Phenolic compounds				
Mass collected, gr	0.673	0.628	0.742	0.681
Concentration, gr/dscf	0.009	0.008	0.010	0.009
Emission level, lb/ton	1.25	0.94	1.08	1.09
Phenol				
Mass collected, gr	0.162	0.152	0.143	0.152
Concentration, gr/dscf	0.002	0.002	0.002	0.002
Emission level, lb/ton	0.30	0.23	0.21	0.25
Formaldehyde				
Mass collected, gr	0.242	0.249	0.231	0.241
Concentration, gr/dscf	0.003	0.003	0.003	0.003
Emission level, lb/ton	0.45	0.37	0.34	0.39

N/A = Not applicable.

TABLE C-3b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Rotoclone
Product: R-11 Building Insulation
(Metric)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	88	88	88	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	3.70	4.54	4.42	4.22
Avg. stack temperture, °C	49.2	49.7	49.2	49.37
Isokinetic, %	99.8	100.0	100.9	100.2
Volume of gas sampled, Nm^3	2.239	2.126	2.193	2.186
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	174.10	176.50	189.80	180.13
Concentration, mg/Nm^3	77.60	82.84	86.37	82.27
Emission level, kg/Mg	2.50	2.03	2.12	2.21
Phenolic compounds				
Mass collected, mg	43.70	40.80	48.20	44.23
Concentration, mg/Nm^3	19.48	19.15	21.93	20.19
Emission level, kg/Mg	0.63	0.47	0.54	0.55
Phenol				
Mass collected, mg	10.50	9.90	9.30	9.9
Concentration, mg/Nm^3	4.68	4.65	4.23	4.52
Emission level, kg/Mg	0.15	0.12	0.11	0.13
Formaldenyde				
Mass collected, mg	15.70	16.20	15.00	15.63
Concentration, mg/Nm^3	7.00	7.60	6.83	7.14
Emission level, kg/Mg	0.23	0.19	0.17	0.20

N/A = Not applicable.

TABLE C-4a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Cooling
Product: R-11 Building Insulation
(English)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	112	112	112	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	0.50	0.78	0.74	0.67
Avg. stack temperature, °F	90.7	101.0	105.1	98.9
Isokinetic, %	99.9	103.8	102.8	102.2
Volume of gas sampled, dscf	70.054	72.904	70.969	71.309
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	0.496	0.360	0.322	0.393
Concentration, gr/dscf	0.007	0.005	0.005	0.006
Emission level, lb/ton	0.35	0.20	0.18	0.24
Phenolic compounds				
Mass collected, gr	0.005	0.005	0.008	0.006
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.00	0.00
Phenol				
Mass collected, gr	0.0	0.003	0.0	0.001
Concentration, gr/dscf	0.0	0.0	0.0	0.0
Emission level, lb/ton	0.0	0.00	0.0	0.00
Formaldehyde				
Mass collected, gr	0.020	0.026	0.018	0.021
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.01	0.01	0.01	0.01

N/A = Not applicable.

TABLE C-4b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Cooling
Product: R-11 Building Insulation
(Metric)

Run number:	4	5	6	Avg.
Date	09/24/81	09/24/81	09/24/81	--
Sampling time, min	112	112	112	--
Glass pull rate, % of design	68	85	86	--
Moisture, % by volume	0.50	0.78	0.74	0.67
Avg. stack temperture, °C	32.6	38.4	40.6	37.2
Isokinetic, %	99.9	103.8	102.8	102.2
Volume of gas sampled, Nm^3	1.984	2.064	2.010	2.019
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	32.20	23.40	20.90	25.50
Concentration, mg/Nm^3	16.20	11.31	10.38	12.63
Emission level, kg/Mg	0.18	0.10	0.09	0.12
Phenolic compounds				
Mass collected, mg	0.30	0.30	0.50	0.37
Concentration, mg/Nm^3	0.15	0.15	0.25	0.18
Emission level, kg/Mg	0.00	0.00	0.00	0.00
Phenol				
Mass collected, mg	0.0	0.20	0.0	0.07
Concentration, mg/Nm^3	0.0	0.10	0.0	0.03
Emission level, kg/Mg	0.0	0.00	0.0	0.00
Formaldehyde				
Mass collected, mg	1.30	1.70	1.20	1.40
Concentration, mg/Nm^3	0.65	0.82	0.60	0.69
Emission level, kg/Mg	0.01	0.01	0.01	0.01

N/A = Not applicable.

TABLE C-5a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Inlet
Product: R-19 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	09/22/81	09/23/81	09/23/81	--
Sampling time, min	144	96	96	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	5.20	5.57	4.60	5.12
Avg. stack temperature, °F	93.3	94.5	88.9	92.2
Isokinetic, %	94.1	96.2	94.4	94.9
Volume of gas sampled, dscf	109.521	75.424	73.006	85.984
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	14.000	8.736	5.285	9.340
Concentration, gr/dscf	0.128	0.116	0.072	0.106
Emission level, lb/ton	52.74	50.55	30.31	44.53
Phenolic compounds				
Mass collected, gr	1.622	1.260	1.010	1.297
Concentration, gr/dscf	0.015	0.017	0.014	0.015
Emission level, lb/ton	6.11	7.29	5.79	6.40
Phenol				
Mass collected, gr	0.453	0.410	0.297	0.387
Concentration, gr/dscf	0.004	0.005	0.004	0.005
Emission level, lb/ton	1.71	2.37	1.70	1.92
Formaldehyde				
Mass collected, gr	0.534	0.279	0.143	0.319
Concentration, gr/dscf	0.005	0.004	0.002	0.004
Emission level, lb/ton	2.01	1.61	0.82	1.48

N/A = Not applicable.

TABLE C-5b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Inlet
Product: R-19 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	09/22/81	09/23/81	09/23/81	--
Sampling time, min	144	96	96	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	5.20	5.57	4.60	5.12
Avg. stack temperture, °C	34.0	34.7	31.6	33.43
Isokinetic, %	94.1	96.2	94.4	94.9
Volume of gas sampled, Nm^3	3.101	2.136	2.067	2.435
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	909.10	567.30	343.20	306.80
Concentration, mg/Nm^3	292.52	265.06	165.67	241.083
Emission level, kg/Mg	26.37	25.28	15.16	22.27
Phenolic compounds				
Mass collected, mg	105.30	81.80	65.60	84.23
Concentration, mg/Nm^3	33.88	38.22	31.67	34.59
Emission level, kg/Mg	3.06	3.65	2.90	3.20
Phenol				
Mass collected, mg	29.40	26.60	19.30	25.10
Concentration, mg/Nm^3	9.46	12.43	9.32	10.40
Emission level, kg/Mg	0.86	1.69	0.85	0.96
Formaldehyde				
Mass collected, mg	34.70	18.10	9.30	20.70
Concentration, mg/Nm^3	11.17	8.46	4.49	8.04
Emission level, kg/Mg	1.01	0.81	0.41	0.74

N/A = Not applicable.

TABLE C-6a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Outlet
Product: R-19 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	09/22/81	09/23/81	09/23/81	--
Sampling time, min	144	108	108	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	5.48	4.17	5.51	5.05
Avg. stack temperature, °F	96.1	85.5	94.4	92.0
Isokinetic, %	96.8	98.3	97.6	97.6
Volume of gas sampled, dscf	61.833	43.388	48.098	51.106
Opacity average, %	10	10	10	--
Particulate matter				
Mass collected, gr	0.930	0.853	1.156	0.980
Concentration, gr/dscf	0.015	0.020	0.024	0.020
Emission level, lb/ton	6.00	7.56	10.04	7.87
Phenolic compounds				
Mass collected, gr	0.308	0.179	0.400	0.296
Concentration, gr/dscf	0.005	0.004	0.008	0.006
Emission level, lb/ton	1.99	1.58	3.48	2.35
Phenol				
Mass collected, gr	0.188	0.151	0.333	0.224
Concentration, gr/dscf	0.003	0.004	0.007	0.005
Emission level, lb/ton	1.21	1.34	2.89	1.81
Formaldehyde				
Mass collected, gr	0.055	0.055	0.119	0.076
Concentration, gr/dscf	0.001	0.001	0.003	0.002
Emission level, lb/ton	0.36	0.49	1.03	0.63

TABLE C-6b. SUMMARY OF TEST RESULTS--LINE A

Sampling Location: Wet ESP Outlet
Product: R-19 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	09/22/81	09/23/81	09/23/81	--
Sampling time, min	144	108	108	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	5.48	4.17	5.51	5.05
Avg. stack temperture, °C	35.6	29.7	34.7	33.33
Isokinetic, %	96.8	98.3	97.6	97.6
Volume of gas sampled, Nm^3	1.751	1.229	1.362	1.447
Opacity average, %	10	10	10	--
Particulate matter				
Mass collected, mg	60.40	55.40	75.10	63.63
Concentration, mg/Nm^3	34.42	45.00	55.02	44.82
Emission level, kg/Mg	3.00	3.78	5.02	3.94
Phenolic compounds				
Mass collected, mg	20.00	11.60	26.00	19.20
Concentration, mg/Nm^3	11.40	9.42	19.05	13.29
Emission level, kg/Mg	1.00	0.79	1.74	1.18
Phenol				
Mass collected, mg	12.20	9.80	21.60	14.53
Concentration, mg/Nm^3	6.95	7.96	15.83	10.25
Emission level, kg/Mg	0.61	0.67	1.45	0.91
Formaldehyde				
Mass collected, mg	3.60	3.60	7.70	4.97
Concentration, mg/Nm^3	2.05	2.92	5.64	3.54
Emission level, kg/Mg	0.18	0.25	0.52	0.32

TABLE C-7a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Rotoclone
Product: R-19 Building Insulation
(English)

Run number:	1*	2	3	Avg.
Date	09/22/81	09/22/81	09/23/81	--
Sampling time, min	66	88	88	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	3.82	3.23	4.94	4.09
Avg. stack temperature, °F	121.3	119.9	121.3	120.6
Isokinetic, %	73.4	100.8	99.4	100.1
Volume of gas sampled, dscf	49.589	79.165	78.033	78.599
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	1.440	2.592	2.835	2.714
Concentration, gr/dscf	0.029	0.033	0.036	0.035
Emission level, lb/ton	3.58	3.68	3.97	3.83
Phenolic compounds				
Mass collected, gr	0.408	0.639	0.493	0.566
Concentration, gr/dscf	0.008	0.008	0.006	0.007
Emission level, lb/ton	1.01	0.91	0.69	0.80
Phenol				
Mass collected, gr	0.009	0.176	0.134	0.155
Concentration, gr/dscf	0.000	0.002	0.002	0.002
Emission level, lb/ton	0.02	0.25	0.19	0.22
Formaldehyde				
Mass collected, gr	0.160	0.231	0.191	0.211
Concentration, gr/dscf	0.003	0.003	0.003	0.003
Emission level, lb/ton	0.40	0.33	0.27	0.30

*Data excluded from average.
N/A = Not applicable.

TABLE C-7b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Rotoclone
Product: R-19 Building Insulation
(Metric)

Run number:	1*	2	3	Avg.
Date	09/22/81	09/22/81	09/23/81	--
Sampling time, min	66	88	88	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	3.82	3.23	4.94	4.09
Avg. stack temperture, °C	49.6	48.8	49.6	49.2
Isokinetic, %	73.4	100.8	99.4	100.1
Volume of gas sampled, Nm³	1.404	2.242	2.210	2.220
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	9.350	168.30	184.10	176.2
Concentration, mg/Nm³	66.45	74.92	83.14	79.03
Emission level, kg/Mg	1.79	1.84	1.99	1.92
Phenolic compounds				
Mass collected, mg	26.50	41.50	32.00	36.75
Concentration, mg/Nm³	18.83	18.47	14.45	16.46
Emission level, kg/Mg	0.51	0.46	0.35	0.41
Phenol				
Mass collected, mg	0.60	11.40	8.70	10.05
Concentration, mg/Nm³	0.43	5.08	3.93	4.51
Emission level, kg/Mg	0.01	0.13	0.10	0.12
Formaldehyde				
Mass collected, mg	10.40	15.00	12.40	13.70
Concentration, mg/Nm³	7.39	6.68	5.60	6.14
Emission level, kg/Mg	0.20	0.17	0.14	0.16

*Data excluded from average.
N/A = Not applicable

TABLE C-8a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Cooling
Product: R-19 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	09/22/81	09/23/81	09/23/81	--
Sampling time, min	140	112	112	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	0.84	0.71	0.69	0.75
Avg. stack temperature, °F	102.5	96.7	102.3	100.5
Isokinetic, %	101.2	101.0	102.3	101.5
Volume of gas sampled, dscf	84.171	67.738	66.264	72.724
Opacity average, %*	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	0.445	0.437	0.263	0.382
Concentration, gr/dscf	0.005	0.007	0.004	0.005
Emission level, lb/ton	0.18	0.24	0.14	0.19
Phenolic compounds				
Mass collected, gr	0.119	0.006	0.006	0.044
Concentration, gr/dscf	0.001	0.000	0.000	0.000
Emission level, lb/ton	0.05	0.00	0.00	0.02
Phenol				
Mass collected, gr	0.005	0.0	0.0	0.002
Concentration, gr/dscf	0.00	0.0	0.0	0.000
Emission level, lb/ton	0.00	0.0	0.0	0.0
Formaldehyde				
Mass collected, gr	0.046	0.026	0.028	0.033
Concentration, gr/dscf	0.001	0.000	0.000	0.000
Emission level, lb/ton	0.02	0.01	0.01	0.01

N/A = Not applicable.

TABLE C-8b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Cooling
Product: R-19 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	09/22/81	09/23/81	09/23/81	--
Sampling time, min	140	112	112	--
Glass pull rate, % of design	92	88	91	--
Moisture, % by volume	0.84	0.71	0.69	0.75
Avg. stack temperture, °C	39.2	36.0	39.0	38.07
Isokinetic, %	101.2	101.0	102.3	101.5
Volume of gas sampled, Nm^3	2.383	1.918	1.876	2.059
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	28.90	28.40	17.10	24.80
Concentration, mg/Nm^3	12.10	14.78	9.09	11.99
Emission level, kg/Mg	0.09	0.12	0.07	0.09
Phenolic compounds				
Mass collected, mg	7.70	0.40	0.40	2.83
Concentration, mg/Nm^3	3.22	0.21	0.21	1.21
Emission level, kg/Mg	0.03	0.00	0.00	0.01
Phenol				
Mass collected, mg	0.30	0.0	0.0	0.10
Concentration, mg/Nm^3	0.13	0.0	0.0	0.04
Emission level, kg/Mg	0.00	0.0	0.0	0.0
Formaldehyde				
Mass collected, mg	3.00	1.70	1.80	2.17
Concentration, mg/Nm^3	1.26	0.88	0.96	1.03
Emission level, kg/Mg	0.01	0.01	0.01	0.01

N/A = Not applicable.

TABLE C-9a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Inlet
Product: Ductboard
(English)

Run number:	1Z	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	5.20	5.12	5.31	5.32	5.24
Avg. stack temperature, °F	91.8	91.0	90.8	89.1	90.7
Isokinetic, %	103.0	94.6	96.1	97.2	97.7
Volume of gas sampled, dscf	110.109	105.007	106.145	104.975	106.559
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	15.951	27.959	29.513	26.120	24.886
Concentration, gr/dscf	0.145	0.266	0.278	0.249	0.235
Emission level, lb/ton	47.37	82.99	85.74	73.15	72.31
Phenolic compounds					
Mass collected, gr	4.991	8.216	8.296	7.809	7.328
Concentration, gr/dscf	0.045	0.078	0.078	0.074	0.069
Emission level, lb/ton	14.82	24.39	24.14	21.87	21.31
Phenol					
Mass collected, gr	1.874	3.309	2.082	3.313	2.645
Concentration, gr/dscf	0.017	0.032	0.020	0.032	0.025
Emission level, lb/ton	5.57	9.82	6.06	9.28	7.68
Formaldehyde					
Mass collected, gr	0.963	0.845	2.033	1.109	1.238
Concentration, gr/dscf	0.009	0.008	0.019	0.011	0.012
Emission level, lb/ton	2.86	2.51	5.91	3.11	3.60

N/A = Not applicable.

TABLE C-9b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Inlet
Product: Ductboard
(Metric)

Run number:	1Z	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	5.20	5.12	5.31	5.32	5.24
Avg. stack temperture, °C	33.2	32.8	32.6	31.7	32.6
Isokinetic, %	103.0	94.6	96.1	97.2	97.7
Volume of gas sampled, Nm^3	3.118	2.973	3.006	2.972	3.017
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	1,035.80	1,815.50	1,916.40	1,696.10	1,615.95
Concentration, mg/Nm^3	331.51	609.28	636.26	569.39	536.61
Emission level, kg/Mg	23.69	41.50	42.87	36.58	36.16
Phenolic compounds					
Mass collected, mg	324.10	533.50	538.70	507.10	475.85
Concentration, mg/Nm^3	103.73	179.04	178.85	170.24	157.97
Emission level, kg/Mg	7.41	12.20	12.07	10.94	10.66
Phenol					
Mass collected, mg	121.70	214.90	135.20	215.10	171.73
Concentration, mg/Nm^3	38.95	72.12	44.89	72.21	57.04
Emission level, kg/Mg	2.79	4.91	3.03	4.64	3.84
Formaldehyde					
Mass collected, mg	62.50	54.90	132.00	72.00	80.35
Concentration, mg/Nm^3	20.00	18.43	43.83	24.17	26.61
Emission level, kg/Mg	1.43	1.26	1.96	1.56	1.55

N/A = Not applicable.

TABLE C-10a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Outlet
Product: Ductboard
(English)

Run number:	1Z*	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	4.89	3.98	4.69	4.16	4.28
Avg. stack temperature, °F	93.4	92.1	91.4	87.5	90.3
Isokinetic, %	112.9	103.9	105.4	102.5	103.9
Volume of gas sampled, dscf	77.541	78.874	74.124	74.587	75.862
Opacity average, %	24.0	17.0	13.0	15.0	--
Particulate matter					
Mass collected, gr	2.033	2.047	2.218	2.281	2.182
Concentration, gr/dscf	0.026	0.026	0.030	0.031	0.029
Emission level, lb/ton	9.16	9.20	9.78	10.08	9.69
Phenolic compounds					
Mass collected, gr	1.335	1.753	2.181	1.589	1.841
Concentration, gr/dscf	0.017	0.022	0.029	0.021	0.024
Emission level, lb/ton	6.02	7.88	9.62	7.03	8.18
Phenol					
Mass collected, gr	0.715	0.758	0.890	0.859	0.836
Concentration, gr/dscf	0.009	0.010	0.012	0.012	0.011
Emission level, lb/ton	3.22	3.41	3.93	3.80	3.71
Formaldehyde					
Mass collected, gr	0.163	0.095	0.139	0.094	0.109
Concentration, gr/dscf	0.002	0.001	0.002	0.001	0.001
Emission level, lb/ton	0.74	0.43	0.61	0.42	0.49

*Data excluded from average.

TABLE C-10b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Wet ESP Outlet
Product: Ductboard
(Metric)

Run number:	1Z*	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	4.89	3.98	4.69	4.16	4.28
Avg. stack temperture, °C	34.1	33.4	33.0	30.8	32.4
Isokinetic, %	112.9	103.9	105.4	102.5	103.9
Volume of gas sampled, Nm^3	2.196	2.233	2.099	2.112	2.148
Opacity average, %	24.0	17.0	13.0	15.0	--
Particulate matter					
Mass collected, mg	132.00	132.90	144.00	148.10	141.67
Concentration, mg/Nm^3	59.99	59.38	68.46	69.97	65.94
Emission level, kg/Mg	4.58	4.60	4.89	5.04	4.84
Phenolic compounds					
Mass collected, mg	86.70	113.80	141.60	103.20	119.53
Concentration, mg/Nm^3	39.40	50.85	67.32	48.76	55.64
Emission level, kg/Mg	3.01	3.94	4.81	3.52	4.09
Phenol					
Mass collected, mg	46.40	49.20	57.80	55.80	54.27
Concentration, mg/Nm^3	21.09	21.98	27.48	26.36	25.27
Emission level, kg/Mg	1.61	1.71	1.97	1.90	1.86
Formaldehyde					
Mass collected, mg	10.60	6.20	9.00	6.10	7.10
Concentration, mg/Nm^3	4.82	2.77	4.28	2.88	3.31
Emission level, kg/Mg	0.37	0.22	0.31	0.21	0.25

*Data excluded from average.

TABLE C-11a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Rotoclone
Product: Ductboard
(English)

Run number:	1Z	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	132	132	132	132	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	5.04	4.39	4.83	3.94	4.55
Avg. stack temperature, °F	122.7	118.0	115.7	116.9	118.3
Isokinetic, %	95.9	100.4	99.8	97.2	98.3
Volume of gas sampled, dscf	108.756	111.267	109.288	112.175	110.372
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	7.469	3.896	4.367	5.080	5.203
Concentration, gr/dscf	0.069	0.035	0.040	0.045	0.047
Emission level, lb/ton	6.33	2.90	3.25	3.78	4.07
Phenolic compounds					
Mass collected, gr	1.947	2.230	2.784	2.338	2.325
Concentration, gr/dscf	0.018	0.020	0.026	0.021	0.021
Emission level, lb/ton	1.65	1.66	2.07	1.74	1.78
Phenol					
Mass collected, gr	0.453	0.622	0.611	0.841	0.632
Concentration, gr/dscf	0.004	0.006	0.006	0.008	0.006
Emission level, lb/ton	0.38	0.46	0.46	0.63	0.48
Formaldehyde					
Mass collected, gr	0.547	0.294	0.162	0.069	0.268
Concentration, gr/dscf	0.005	0.003	0.002	0.001	0.003
Emission level, lb/ton	0.46	0.22	0.12	0.05	0.21

N/A = Not applicable.

TABLE C-11b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Rotoclone
Product: Ductboard
(Metric)

Run number:	1Z	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	132	132	132	132	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	5.04	4.39	4.83	3.94	4.55
Avg. stack temperture, °C	50.4	47.8	46.5	47.2	4.80
Isokinetic, %	95.9	100.4	99.8	97.2	98.3
Volume of gas sampled, Nm^3	3.080	3.151	3.095	3.176	3.126
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	485.00	253.00	283.60	329.90	337.88
Concentration, mg/Nm^3	157.16	80.13	91.45	103.64	108.10
Emission level, kg/Mg	3.17	1.45	1.63	1.89	2.04
Phenolic compounds					
Mass collected, mg	126.40	144.80	180.80	151.80	150.95
Concentration, mg/Nm^3	40.96	45.86	58.30	47.69	48.20
Emission level, kg/Mg	0.83	0.83	1.04	0.87	0.89
Phenol					
Mass collected, mg	29.40	40.40	39.70	54.60	41.03
Concentration, mg/Nm^3	9.53	12.80	12.80	17.15	13.07
Emission level, kg/Mg	0.19	0.23	0.23	0.32	0.24
Formaldehyde					
Mass collected, mg	35.50	19.10	10.50	4.50	17.40
Concentration, mg/Nm^3	11.50	6.05	3.39	1.41	5.59
Emission level, kg/Mg	0.23	0.11	0.06	0.03	0.11

N/A = Not applicable.

TABLE C-12a. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Cooling
Product: Ductboard
(English)

Run number:	1Z	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	140	140	140	140	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	0.70	0.59	0.71	1.01	0.75
Avg. stack temperature, °F	87.0	99.8	100.9	80.8	92.13
Isokinetic, %	99.2	101.0	107.6	101.0	102.2
Volume of gas sampled, dscf	65.347	59.262	61.103	68.151	63.46
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	0.402	0.537	0.678	0.513	0.533
Concentration, gr/dscf	0.006	0.009	0.011	0.008	0.009
Emission level, lb/ton	0.14	0.16	0.19	0.15	0.16
Phenolic compounds					
Mass collected, gr	0.012	0.014	0.014	0.012	0.013
Concentration, gr/dscf	0.000	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.00	0.00	0.00
Phenol					
Mass collected, gr	0.002	0.003	0.002	0.003	0.003
Concentration, gr/dscf	0.000	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.00	0.00	0.00
Formaldehyde					
Mass collected, gr	0.040	0.039	0.049	0.039	0.042
Concentration, gr/dscf	0.001	0.001	0.001	0.001	0.001
Emission level, lb/ton	0.01	0.01	0.01	0.01	0.01

N/A = Not applicable.

TABLE C-12b. SUMMARY OF TEST RESULTS--LINE A
Sampling Location: Cooling
Product: Ductboard
(Metric)

Run number:	1Z	2Z	3Z	4Z	Avg.
Date	10/17/81	10/18/81	10/18/81	10/19/81	--
Sampling time, min	140	140	140	140	--
Glass pull rate, % of design	86	94	94	97	--
Moisture, % by volume	0.70	0.59	0.71	1.01	0.75
Avg. stack temperture, °C	30.5	37.7	38.3	27.1	33.4
Isokinetic, %	99.2	101.0	107.6	101.0	102.2
Volume of gas sampled, Nm³	1.850	1.678	1.730	1.930	1.797
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	26.10	34.90	44.00	33.30	34.58
Concentration, mg/Nm³	14.08	20.75	25.38	17.22	19.36
Emission level, kg/Mg	0.07	0.08	0.10	0.08	0.08
Phenolic compounds					
Mass collected, mg	0.80	0.90	0.90	0.80	0.85
Concentration, mg/Nm³	0.43	0.54	0.52	0.41	0.48
Emission level, kg/Mg	0.00	0.00	0.00	0.00	0.00
Phenol					
Mass collected, mg	0.10	0.20	0.10	0.20	0.15
Concentration, mg/Nm³	0.05	0.12	0.06	0.10	0.08
Emission level, kg/Mg	0.00	0.00	0.00	0.00	0.00
Formaldehyde					
Mass collected, mg	2.60	2.50	3.20	2.50	2.70
Concentration, mg/Nm³	1.40	1.49	1.85	1.29	1.51
Emission level, kg/Mg	0.01	0.01	0.01	0.01	0.01

N/A = Not applicable.

TABLE C-13a. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Incinerator-Curing
Product: Heavy Density Insulation
(English)

Run number:	1*	2	3	4	Avg.
Date	12/09/81	12/10/81	12/11/81	12/11/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	90	90	89	89	--
Moisture, % by volume	8.63	8.00	8.22	8.35	8.19
Avg. stack temperature, °F	1,190.5	1,186.1	1,191.2	1,190.6	1,189.3
Isokinetic, %	99.3	98.0	99.7	99.1	98.9
Volume of gas sampled, dscf	110.804	116.751	114.994	115.082	115.610
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	7.404	1.863	0.511	0.460	0.945
Concentration, gr/dscf	0.067	0.016	0.005	0.004	0.008
Emission level, lb/ton	1.23	0.32	0.09	0.08	0.16
Phenolic compounds					
Mass collected, gr	0.097	0.032	0.005	0.005	0.014
Concentration, gr/dscf	0.001	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.02	0.01	0.00	0.00	0.00
Phenol					
Mass collected, gr	0.025	0.017	0.005	0.008	0.010
Concentration, gr/dscf	0.000	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.00	0.00	0.00
Formaldehyde					
Mass collected, gr	0.776	0.225	0.060	0.054	0.113
Concentration, gr/dscf	0.007	0.002	0.001	0.001	0.001
Emission level, lb/ton	0.13	0.04	0.00	0.01	0.02

*Data excluded from average.
N/A = Not applicable.

TABLE C-13b. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Incinerator-Curing
Product: Heavy Density Insulation
(Metric)

Run number:	1*	2	3	4	Avg.
Date	12/09/81	12/10/81	12/11/81	12/11/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	90	90	89	89	--
Moisture, % by volume	8.63	8.00	8.22	8.35	8.19
Avg. stack temperture, °C	643.6	641.1	644.0	643.7	642.9
Isokinetic, %	99.3	98.0	99.7	99.1	98.9
Volume of gas sampled, Nm^3	3.138	3.306	3.256	3.259	3.274
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	480.80	121.00	33.20	29.90	61.37
Concentration, mg/Nm^3	152.92	36.52	10.17	9.16	18.62
Emission level, kg/Mg	0.61	0.16	0.05	0.04	0.08
Phenolic compounds					
Mass collected, mg	6.30	2.10	0.30	0.30	0.90
Concentration, mg/Nm^3	2.00	0.63	0.09	0.09	0.27
Emission level, kg/Mg	0.01	0.01	0.00	0.00	0.00
Phenol					
Mass collected, mg	1.60	1.10	0.30	0.50	0.63
Concentration, mg/Nm^3	0.51	0.33	0.09	0.15	0.19
Emission level, kg/Mg	0.00	0.00	0.00	0.00	0.00
Formaldehyde					
Mass collected, mg	50.40	14.60	3.90	3.50	7.33
Concentration, mg/Nm^3	16.03	4.41	1.20	1.07	2.23
Emission level, kg/Mg	0.07	0.02	0.00	0.01	0.01

*Data excluded from average.
N/A = Not applicable.

TABLE C-14a. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Forming Duct A
Product: Heavy Density Insulation
(English)

Run number:	1	2	3	Avg.
Date	12/09/81	12/10/81	12/11/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	7.58	7.60	7.92	7.70
Avg. stack temperature, °F	107.3	104.9	106.3	106.2
Isokinetic, %	99.9	101.0	101.4	100.8
Volume of gas sampled, dscf	63.083	58.294	53.846	60.408
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	9.651	9.331	6.349	8.225
Concentration, gr/dscf	0.153	0.160	0.106	0.140
Emission level, lb/ton	5.85	5.63	3.83	5.10
Phenolic compounds				
Mass collected, gr	1.092	1.218	0.809	1.013
Concentration, gr/dscf	0.017	0.021	0.014	0.017
Emission level, lb/ton	0.66	0.74	0.49	0.63
Phenol				
Mass collected, gr	0.899	0.647	0.305	0.601
Concentration, gr/dscf	0.014	0.011	0.005	0.010
Emission level, lb/ton	0.55	0.39	0.18	0.37
Formaldehyde				
Mass collected, gr	0.573	0.858	0.250	0.546
Concentration, gr/dscf	0.009	0.015	0.004	0.009
Emission level, lb/ton	0.35	0.52	0.15	0.34

N/A = Not applicable.

TABLE C-14b. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Forming Duct A
Product: Heavy Density Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	12/09/81	12/10/81	12/11/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	7.58	7.60	7.92	7.70
Avg. stack temperture, °C	41.8	40.5	41.3	41.2
Isokinetic, %	99.9	101.0	101.4	100.8
Volume of gas sampled, Nm³	1.786	1.651	1.685	1.711
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	626.70	605.90	412.30	548.30
Concentration, mg/Nm³	350.10	366.29	242.79	319.72
Emission level, kg/Mg	2.93	2.82	1.92	2.56
Phenolic compounds				
Mass collected, mg	70.90	79.10	52.50	67.50
Concentration, mg/Nm³	39.61	47.82	30.92	39.45
Emission level, kg/Mg	0.33	0.35	0.25	0.32
Phenol				
Mass collected, mg	58.40	42.00	19.80	40.07
Concentration, mg/Nm³	32.62	25.39	11.66	23.23
Emission level, kg/Mg	0.28	0.20	0.09	0.19
Formaldehyde				
Mass collected, mg	37.20	55.70	16.20	36.37
Concentration, mg/Nm³	20.78	33.67	9.54	21.33
Emission level, kg/Mg	0.18	0.26	0.08	0.17

N/A = Not applicable.

TABLE C-15a. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Forming Duct B
Product: Heavy Density Insulation
(English)

Run number:	1	2	3	Avg.
Date	12/09/81	12/10/81	12/11/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	7.92	7.57	7.86	7.78
Avg. stack temperature, °F	106.7	106.8	110.8	108.1
Isokinetic, %	106.7	107.5	108.2	107.5
Volume of gas sampled, dscf	59.461	66.120	65.246	63.609
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	2.419	2.747	2.784	2.582
Concentration, gr/dscf	0.041	0.042	0.043	0.042
Emission level, lb/ton	1.49	1.69	1.71	1.63
Phenolic compounds				
Mass collected, gr	0.767	0.790	0.667	0.722
Concentration, gr/dscf	0.013	0.012	0.010	0.012
Emission level, lb/ton	0.47	0.49	0.41	0.46
Phenol				
Mass collected, gr	0.627	0.431	0.367	0.463
Concentration, gr/dscf	0.011	0.007	0.006	0.008
Emission level, lb/ton	0.39	0.27	0.23	0.30
Formaldehyde				
Mass collected, gr	0.219	0.234	0.183	0.207
Concentration, gr/dscf	0.004	0.004	0.003	0.003
Emission level, lb/ton	0.14	0.14	0.11	0.13

N/A = Not applicable.

TABLE C-15b. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Forming Duct B
Product: Heavy Density Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	12/09/81	12/10/81	12/11/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	7.92	7.57	7.86	7.78
Avg. stack temperture, °C	41.5	41.5	43.8	42.3
Isokinetic, %	106.7	107.5	108.2	107.5
Volume of gas sampled, Nm³	1.684	1.872	1.848	1.801
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	157.10	178.40	180.80	172.10
Concentration, mg/Nm³	93.11	95.08	97.65	95.28
Emission level, kg/Mg	0.75	0.85	0.86	0.80
Phenolic compounds				
Mass collected, mg	49.80	51.30	43.30	48.13
Concentration, mg/Nm³	29.52	27.34	23.39	26.75
Emission level, kg/Mg	0.24	0.25	0.21	0.23
Phenol				
Mass collected, mg	40.70	28.00	23.80	30.83
Concentration, mg/Nm³	24.12	14.92	12.89	17.31
Emission level, kg/Mg	0.20	0.14	0.12	0.15
Formaldehyde				
Mass collected, mg	14.20	15.20	11.90	13.77
Concentration, mg/Nm³	8.42	8.11	6.43	7.65
Emission level, kg/Mg	0.07	0.07	0.06	0.07

N/A = Not applicable.

TABLE C-16a. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Forming Duct C
Product: Heavy Density Insulation
(English)

Run number:	1	2	3	Avg.
Date	12/09/81	12/10/81	12/11/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	5.55	6.12	5.38	5.68
Avg. stack temperature, °F	96.7	97.8	93.6	96.0
Isokinetic, %	106.4	102.0	101.2	103.2
Volume of gas sampled, dscf	44.874	42.475	42.277	43.209
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	6.134	3.500	3.556	4.283
Concentration, gr/dscf	0.137	0.082	0.084	0.101
Emission level, lb/ton	7.32	4.38	4.51	5.40
Phenolic compounds				
Mass collected, gr	0.684	0.465	0.453	0.520
Concentration, gr/dscf	0.015	0.011	0.012	0.012
Emission level, lb/ton	0.82	0.58	0.57	0.66
Phenol				
Mass collected, gr	0.399	0.265	0.228	0.290
Concentration, gr/dscf	0.009	0.006	0.005	0.007
Emission level, lb/ton	0.48	0.33	0.29	0.37
Formaldehyde				
Mass collected, gr	0.336	0.373	0.209	0.298
Concentration, gr/dscf	0.008	0.009	0.005	0.007
Emission level, lb/ton	0.40	0.47	0.27	0.38

N/A = Not applicable.

TABLE C-16b. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Forming Duct C
Product: Heavy Density Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	12/09/81	12/10/81	12/11/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	5.55	6.12	5.38	5.68
Avg. stack temperture, °C	35.9	36.5	34.2	35.5
Isokinetic, %	106.4	102.0	101.2	103.2
Volume of gas sampled, Nm^3	1.271	1.203	1.197	1.224
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	398.30	227.30	230.90	285.5
Concentration, mg/Nm^3	312.79	188.59	192.47	231.28
Emission level, kg/Mg	3.66	2.19	2.26	2.70
Phenolic compounds				
Mass collected, mg	44.40	30.20	29.40	34.67
Concentration, mg/Nm^3	34.87	25.06	24.51	28.144
Emission level, kg/Mg	0.41	0.29	0.29	0.33
Phenol				
Mass collected, mg	25.90	17.20	14.80	19.30
Concentration, mg/Nm^3	20.34	14.27	12.34	12.32
Emission level, kg/Mg	0.24	0.17	0.15	0.19
Formaldehyde				
Mass collected, mg	21.80	24.20	13.60	19.87
Concentration, mg/Nm^3	17.12	20.08	11.34	16.18
Emission level, kg/Mg	0.20	0.24	0.14	0.19

N/A = Not applicable.

TABLE C-17a. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Mixing Chamber
Product: Heavy Density Insulation
(English)

Run number:	1	2	3	Avg.
Date	12/09/81	12/10/81	12/11/81	--
Sampling time, min	147	147	147	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	7.53	7.19	6.90	7.21
Avg. stack temperature, °F	262.6	262.1	265.6	263.4
Isokinetic, %	107.4	105.2	102.9	105.2
Volume of gas sampled, dscf	80.255	80.050	77.730	79.345
Opacity average, %	5	5	5	--
Particulate matter				
Mass collected, gr	2.156	2.091	1.885	1.991
Concentration, gr/dscf	0.027	0.026	0.024	0.026
Emission level, lb/ton	4.12	4.11	3.80	4.01
Phenolic compounds				
Mass collected, gr	0.581	0.370	0.501	0.471
Concentration, gr/dscf	0.007	0.005	0.006	0.006
Emission level, lb/ton	1.11	0.73	1.01	0.95
Phenol				
Mass collected, gr	0.494	0.353	0.245	0.355
Concentration, gr/dscf	0.006	0.004	0.003	0.005
Emission level, lb/ton	0.94	0.69	0.49	0.69
Formaldehyde				
Mass collected, gr	0.334	0.388	0.251	0.316
Concentration, gr/dscf	0.004	0.005	0.003	0.004
Emission level, lb/ton	0.64	0.76	0.51	0.64

TABLE C-17b. SUMMARY OF TEST RESULTS--LINE B
Sampling Location: Mixing Chamber
Product: Heavy Density Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	12/09/81	02/10/81	12/11/81	--
Sampling time, min	147	147	147	--
Glass pull rate, % of design	90	90	89	--
Moisture, % by volume	7.53	7.19	6.90	7.21
Avg. stack temperture, °C	128.1	127.8	129.8	128.6
Isokinetic, %	107.4	105.2	102.9	105.2
Volume of gas sampled, Nm^3	2.272	2.267	2.201	2.247
Opacity average, %	5	5	5	--
Particulate matter				
Mass collected, mg	140.00	135.80	122.40	132.73
Concentration, mg/Nm^3	61.48	59.78	55.49	58.92
Emission level, kg/Mg	2.06	2.06	1.90	2.01
Phenolic compounds				
Mass collected, mg	37.70	24.00	32.50	31.40
Concentration, mg/Nm^3	16.55	10.57	14.74	13.95
Emission level, kg/Mg	0.56	0.37	0.51	0.48
Phenol				
Mass collected, mg	32.10	22.90	15.90	23.63
Concentration, mg/Nm^3	14.10	10.08	7.21	10.46
Emission level, kg/Mg	0.47	0.35	0.25	0.35
Formaldehyde				
Mass collected, mg	21.70	25.20	16.30	21.07
Concentration, mg/Nm^3	9.53	11.09	7.39	9.34
Emission level, kg/Mg	0.32	0.38	0.26	0.32

TABLE C-18a. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Wet ESP Inlet
Product: R-11 Building Insulation
(English)

Run number:	1	Avg.
Date	08/26/81	--
Sampling time, min	150	--
Glass pull rate, % of design	90	--
Moisture, % by volume	7.72	--
Avg. stack temperature, °F	103.0	--
Isokinetic, %	105.0	--
Volume of gas sampled, dscf	63.445	--
Opacity average, %	N/A	--
Particulate matter		
Mass collected, gr	71.598	--
Concentration, gr/dscf	1.130	--
Emission level, lb/ton	174.00	--
Phenolic compounds		
Mass collected, gr	12.460	--
Concentration, gr/dscf	0.196	--
Emission level, lb/ton	30.28	--
Phenol		
Mass collected, gr	1.380	--
Concentration, gr/dscf	0.022	--
Emission level, lb/ton	3.35	--
Formaldehyde		
Mass collected, gr	4.477	--
Concentration, gr/dscf	0.071	--
Emission level, lb/ton	10.80	--

N/A = Not applicable.

TABLE C-18b. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Wet ESP Inlet
Product: R-11 Building Insulation
(Metric)

Run number:	1	Avg.
Date	08/26/81	--
Sampling time, min	150	--
Glass pull rate, % of design	90	--
Moisture, % by volume	7.72	--
Avg. stack temperture, °C	39.4	--
Isokinetic, %	105.0	--
Volume of gas sampled, Nm^3	1.796	--
Opacity average, %	N/A	--
Particulate matter		
Mass collected, mg	4,649.20	--
Concentration, mg/Nm^3	2,582.42	--
Emission level, kg/Mg	87.00	--
Phenolic compounds		
Mass collected, mg	809.10	--
Concentration, mg/Nm^3	449.42	--
Emission level, kg/Mg	15.14	--
Phenol		
Mass collected, mg	89.60	--
Concentration, mg/Nm^3	49.77	--
Emission level, kg/Mg	1.68	--
Formaldehyde		
Mass collected, mg	290.70	--
Concentration, mg/Nm^3	161.47	--
Emission level, kg/Mg	5.40	--

N/A = Not applicable.

TABLE C-19a. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Wet ESP Outlet
Product: R-11 Building Insulation
(English)

Run number:	1*	Avg.
Date	08/26/81	--
Sampling time, min	160	--
Glass pull rate, % of design	90	--
Moisture, % by volume	6.11	--
Avg. stack temperature, °F	110.5	--
Isokinetic, %	100.6	--
Volume of gas sampled, dscf	107.052	--
Opacity average, %	N/A	--
Particulate matter		
Mass collected, gr	2.871	--
Concentration, gr/dscf	0.027	--
Emission level, lb/ton	5.16	--
Phenolic compounds		
Mass collected, gr	1.328	--
Concentration, gr/dscf	0.012	--
Emission level, lb/ton	2.38	--
Phenol		
Mass collected, gr	0.748	--
Concentration, gr/dscf	0.007	--
Emission level, lb/ton	1.34	--
Formaldehyde		
Mass collected, gr	0.320	--
Concentration, gr/dscf	0.003	--
Emission level, lb/ton	0.58	--

*Data excluded.
N/A = Not applicable.

TABLE C-19b. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Wet ESP Outlet
Product: R-11 Building Insulation
(Metric)

Run number:	1*	Avg.
Date	08/26/81	--
Sampling time, min	160	--
Glass pull rate, % of design	90	--
Moisture, % by volume	6.11	--
Avg. stack temperture, °C	43.6	--
Isokinetic, %	100.6	--
Volume of gas sampled, Nm^3	3.031	--
Opacity average, %	N/A	--
Particulate matter		
Mass collected, mg	186.40	--
Concentration, mg/Nm^3	61.361	--
Emission level, kg/Mg	2.58	--
Phenolic compounds		
Mass collected, mg	86.20	--
Concentration, mg/Nm^3	28.376	--
Emission level, kg/Mg	1.19	--
Phenol		
Mass collected, mg	48.60	--
Concentration, mg/Nm^3	15.999	--
Emission level, kg/Mg	0.67	--
Formaldehyde		
Mass collected, mg	20.80	--
Concentration, mg/Nm^3	6.847	--
Emission level, kg/Mg	0.29	--

*Data excluded.
N/A = Not applicable.

TABLE C-20a. SUMMARY OF TEST RESULTS--LINE C

Sampling Location: HVAF Inlet
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/81	08/27/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	5.69	6.05	8.30	6.68
Avg. stack temperature, °F	94.4	96.3	95.3	95.3
Isokinetic, %	98.0	97.4	100.3	98.6
Volume of gas sampled, dscf	49.816	44.472	461.191	46.826
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	5.202	7.928	6.396	6.509
Concentration, gr/dscf	0.104	0.178	0.138	0.140
Emission level, lb/ton	4.96	7.36	5.77	6.03
Phenolic compounds				
Mass collected, gr	0.818	0.824	0.958	0.867
Concentration, gr/dscf	0.016	0.019	0.021	0.019
Emission level, lb/ton	0.78	0.77	0.86	0.80
Phenol				
Mass collected, gr	0.367	0.420	0.339	0.375
Concentration, gr/dscf	0.007	0.010	0.007	0.008
Emission level, lb/ton	0.35	0.39	0.31	0.35
Formaldehyde				
Mass collected, gr	0.271	0.357	0.353	0.327
Concentration, gr/dscf	0.005	0.008	0.008	0.007
Emission level, lb/ton	0.26	0.33	0.32	0.30

N/A = Not applicable.

TABLE C-20b. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: HVAF Inlet
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/81	08/27/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	5.69	6.05	8.30	6.68
Avg. stack temperture, °C	34.7	35.7	35.2	35.2
Isokinetic, %	98.0	97.4	100.3	98.6
Volume of gas sampled, Nm^3	1.411	1.259	1.308	1.326
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	337.80	514.80	415.30	422.63
Concentration, mg/Nm^3	238.97	407.94	316.84	321.25
Emission level, kg/Mg	2.48	3.68	2.89	3.02
Phenolic compounds				
Mass collected, mg	53.10	53.50	62.20	56.27
Concentration, mg/Nm^3	37.56	42.39	47.45	42.47
Emission level, kg/Mg	0.39	0.39	0.43	0.40
Phenol				
Mass collected, mg	23.80	27.30	22.00	24.37
Concentration, mg/Nm^3	16.84	21.63	16.78	18.42
Emission level, kg/Mg	0.18	0.20	0.16	0.18
Formaldehyde				
Mass collected, mg	17.60	23.20	22.90	21.23
Concentration, mg/Nm^3	12.45	18.38	17.47	16.10
Emission level, kg/Mg	0.13	0.17	0.16	0.15

N/A = Not applicable.

TABLE C-21a. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: HVAF Outlet
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/81	08/27/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	5.37	6.39	6.55	6.10
Avg. stack temperature, °F	125.3	128.9	129.3	127.8
Isokinetic, %	101.0	103.8	103.0	102.6
Volume of gas sampled, dscf	68.312	67.556	66.778	67.549
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	1.756	1.637	1.532	1.642
Concentration, gr/dscf	0.026	0.024	0.023	0.024
Emission level, lb/ton	1.25	1.10	1.04	1.13
Phenolic compounds				
Mass collected, gr	0.491	0.508	0.516	0.505
Concentration, gr/dscf	0.007	0.008	0.008	0.008
Emission level, lb/ton	0.35	0.34	0.35	0.35
Phenol				
Mass collected, gr	0.399	0.419	0.430	0.416
Concentration, gr/dscf	0.006	0.006	0.006	0.006
Emission level, lb/ton	0.29	0.28	0.29	0.29
Formaldehyde				
Mass collected, gr	0.194	0.209	0.202	0.202
Concentration, gr/dscf	0.003	0.003	0.003	0.003
Emission level, lb/ton	0.14	0.14	0.14	0.14

N/A = Not applicable.

TABLE C-21b. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: HVAF Outlet
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/71	08/27/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	5.37	6.39	6.55	6.10
Avg. stack temperture, °C	51.8	53.8	54.1	53.2
Isokinetic, %	101.0	103.8	103.0	102.6
Volume of gas sampled, Nm^3	1.934	1.913	1.891	1.913
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	114.00	106.30	99.50	106.60
Concentration, mg/Nm^3	58.81	55.45	52.51	55.59
Emission level, kg/Mg	0.63	0.55	0.52	0.57
Phenolic compounds				
Mass collected, mg	31.90	33.00	33.50	32.80
Concentration, mg/Nm^3	16.46	17.21	17.68	17.12
Emission level, kg/Mg	0.18	0.17	0.18	0.18
Phenol				
Mass collected, mg	25.90	27.20	27.90	27.00
Concentration, mg/Nm^3	13.36	14.19	14.72	14.09
Emission level, kg/Mg	0.15	0.14	0.15	0.15
Formaldehyde				
Mass collected, mg	12.60	13.60	13.10	13.10
Concentration, mg/Nm^3	6.50	7.09	6.91	6.84
Emission level, kg/Mg	0.07	0.07	0.07	0.07

N/A = Not applicable.

TABLE C-22a. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Cooling
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/81	08/27/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	1.52	2.10	1.67	1.76
Avg. stack temperature, °F	219.7	231.2	235.1	228.7
Isokinetic, %	96.1	101.6	98.8	98.8
Volume of gas sampled, dscf	93.212	90.844	103.256	95.771
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	1.676	1.756	1.797	1.743
Concentration, gr/dscf	0.018	0.019	0.017	0.018
Emission level, lb/ton	0.14	0.13	0.14	0.14
Phenolic compounds				
Mass collected, gr	0.211	0.185	0.171	0.19
Concentration, gr/dscf	0.002	0.002	0.002	0.002
Emission level, lb/ton	0.02	0.01	0.01	0.01
Phenol				
Mass collected, gr	0.082	0.077	0.045	0.068
Concentration, gr/dscf	0.001	0.001	0.000	0.001
Emission level, lb/ton	0.01	0.01	0.00	0.01
Formaldehyde				
Mass collected, gr	0.162	0.253	0.239	0.218
Concentration, gr/dscf	0.002	0.003	0.002	0.002
Emission level, lb/ton	0.01	0.02	0.02	0.02

N/A = Not applicable.

TABLE C-22b. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Cooling
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/81	08/27/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	1.52	2.10	1.67	1.76
Avg. stack temperture, °C	104.3	110.7	112.8	109.27
Isokinetic, %	96.1	101.6	98.8	98.8
Volume of gas sampled, Nm³	2.639	2.572	2.924	2.712
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	108.80	114.50	116.70	113.33
Concentration, mg/Nm³	41.13	44.42	39.83	41.79
Emission level, kg/Mg	0.07	0.07	0.07	0.07
Phenolic compounds				
Mass collected, mg	13.70	12.00	11.10	12.27
Concentration, mg/Nm³	5.18	4.66	3.79	4.54
Emission level, kg/Mg	0.01	0.01	0.01	0.01
Phenol				
Mass collected, mg	5.30	5.00	2.90	4.40
Concentration, mg/Nm³	2.00	1.94	0.99	1.64
Emission level, kg/Mg	0.01	0.01	0.00	0.01
Formaldehyde				
Mass collected, mg	10.50	16.40	15.50	14.13
Concentration, mg/Nm³	3.97	6.36	5.29	5.21
Emission level, kg/Mg	0.01	0.01	0.01	0.01

N/A = Not applicable.

TABLE C-23a. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Asphalt
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/81	08/27/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	1.62	2.30	0.0	1.31
Avg. stack temperature, °F	101.6	92.8	98.6	97.67
Isokinetic, %	99.7	100.4	100.0	100.03
Volume of gas sampled, dscf	90.209	85.668	86.999	87.625
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	0.953	1.178	1.016	1.049
Concentration, gr/dscf	0.011	0.014	0.012	0.012
Emission level, lb/ton	0.05	0.06	0.05	0.05
Phenolic compounds				
Mass collected, gr	0.009	0.012	0.011	0.011
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.00	0.00
Phenol				
Mass collected, gr	0.083	0.179	0.069	0.110
Concentration, gr/dscf	0.001	0.002	0.001	0.001
Emission level, lb/ton	0.00	0.01	0.00	0.00
Formaldehyde				
Mass collected, gr	0.002	0.002	0.002	0.002
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.00	0.00

N/A = Not applicable.

TABLE C-23b. SUMMARY OF TEST RESULTS--LINE C
Sampling Location: Asphalt
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	08/26/81	08/27/81	08/27/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	90	93	93	--
Moisture, % by volume	1.62	2.30	0.0	1.31
Avg. stack temperture, °C	38.7	33.8	37.0	36.5
Isokinetic, %	99.7	100.4	100.0	100.0
Volume of gas sampled, Nm^3	2.554	2.426	2.463	2.481
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	61.90	76.50	66.00	68.13
Concentration, mg/Nm^3	24.18	31.47	26.73	27.46
Emission level, kg/Mg	0.03	0.03	0.03	0.03
Phenolic compounds				
Mass collected, mg	0.06	0.80	0.70	0.70
Concentration, mg/Nm^3	0.23	0.33	0.28	0.28
Emission level, kg/Mg	0.00	0.00	0.00	0.00
Phenol				
Mass collected, mg	5.40	11.60	4.50	7.17
Concentration, mg/Nm^3	2.11	4.77	1.82	2.90
Emission level, kg/Mg	0.00	0.01	0.00	0.00
Formaldehyde				
Mass collected, mg	0.10	0.10	0.10	0.10
Concentration, mg/Nm^3	0.04	0.04	0.04	0.04
Emission level, kg/Mg	0.00	0.00	0.00	0.00

N/A = Not applicable.

TABLE C-24a. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Wet ESP Inlet Product: R-11 Building Insulation
(English)

Run number:	1*	2	3	4	5	6	7	Avg.
Date	04/07/81	04/08/81	04/09/81	04/10/81	04/10/81	04/11/81	04/14/81	--
Sampling time, min	144	168	168	144	144	144	117	--
Glass pull rate, % of design	107	105	103	107	107	105	105	--
Moisture, % by volume	10.81	11.35	10.52	11.87	11.98	11.59	11.52	11.47
Avg. stack temperature, °F	116.8	117.5	111.5	115.2	120.2	117.7	119.3	116.9
Isokinetic, %	108.0	106.9	103.4	106.2	107.7	106.5	102.0	105.5
Volume of gas sampled, dscf	115.306	138.770	133.903	108.471	109.816	110.618	83.319	114.150
Opacity average, %	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--
Particulate matter								
Mass collected, gr	13.718	16.406	14.336	14.447	12.958	14.165	11.924	14.039
Concentration, gr/dscf	0.119	0.118	0.107	0.133	0.118	0.128	0.143	0.125
Emission level, lb/ton	11.79	12.42	11.37	12.62	11.17	12.50	13.57	12.28
Phenolic compounds								
Mass collected, lb	4.093	4.719	3.699	3.425	3.305	3.097	3.172	3.60
Concentration, gr/dscf	0.036	0.034	0.028	0.032	0.030	0.028	0.038	0.032
Emission level, lb/ton	3.52	3.57	2.93	2.99	2.85	2.73	3.61	3.11
Phenol								
Mass collected, gr	1.426	1.962	1.144	1.015	1.021	1.021	1.004	1.19
Concentration, gr/dscf	0.012	0.014	0.009	0.009	0.009	0.009	0.012	0.010
Emission level, lb/ton	1.23	1.49	0.91	0.89	0.88	0.90	1.14	1.04
Formaldehyde								
Mass collected, gr	2.216	2.612	2.176	2.101	2.065	2.114	1.763	2.14
Concentration, gr/dscf	0.019	0.019	0.016	0.019	0.019	0.019	0.021	0.019
Emission level, lb/ton	1.90	1.98	1.73	1.84	1.78	1.87	2.01	1.87

*Data excluded from average because the product during this run was R-19 building insulation.
N/A = Not applicable.

TABLE C-24b. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Wet ESP Inlet Product: R-11 Building Insulation
(Metric)

Run number:	1*	2	3	4	5	6	7	Avg.
Date	04/07/81	04/08/81	04/09/81	04/10/81	04/10/81	04/11/81	04/14/81	--
Sampling time, min	144	168	168	144	144	144	117	--
Glass pull rate, % of design	107	105	103	107	107	105	105	--
Moisture, % by volume	10.81	11.35	10.52	11.87	11.98	11.59	11.52	11.47
Avg. stack temperature, °F	47.1	47.5	44.2	46.2	49.0	47.6	48.5	47.2
Isokinetic, %	108.0	106.9	103.4	106.2	107.7	106.5	102.0	105.5
Volume of gas sampled, Nm^3	3.265	3.929	3.792	3.071	3.110	3.132	2.359	3.232
Opacity average, %	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--
Particulate matter								
Mass collected, mg	890.80	1,065.30	930.90	938.10	841.40	919.80	774.30	911.63
Concentration, mg/Nm^3	272.25	270.53	244.99	304.77	270.01	293.03	327.50	285.14
Emission level, kg/Mg	5.90	6.21	5.69	6.31	5.59	6.25	6.79	6.14
Phenolic compounds								
Mass collected, mg	265.80	306.40	240.20	222.40	214.60	201.10	206.00	231.78
Concentration, mg/Nm^3	81.24	77.81	63.22	72.25	68.87	64.07	87.13	72.23
Emission level, kg/Mg	1.76	1.79	1.47	1.50	1.43	1.37	1.81	1.56
Phenol								
Mass collected, mg	92.60	127.40	74.30	65.90	66.30	66.30	65.20	77.57
Concentration, mg/Nm^3	28.30	32.35	19.55	21.41	21.28	21.12	27.58	23.88
Emission level, kg/Mg	0.67	0.75	0.46	0.45	0.44	0.45	0.57	0.52
Formaldehyde								
Mass collected, mg	143.90	169.60	141.30	136.40	134.10	137.30	114.50	138.87
Concentration, mg/Nm^3	43.98	43.07	37.19	44.31	43.03	43.74	48.43	43.40
Emission level, kg/Mg	0.95	0.99	0.87	0.92	0.89	0.94	1.01	0.94

*Data excluded from average because the product was R-19 building insulation.
N/A = Not applicable.

TABLE C-25a. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Forming
Product: R-11 Building Insulation
(English)

Run number:	1*	2*	3	4	Avg.
Date	04/13/81	04/13/81	04/13/81	04/13/81	--
Sampling time, min	72	68	72	72	--
Glass pull rate, % of design	106	106	106	106	--
Moisture, % by volume	15.05	15.68	15.75	14.29	15.02
Avg. stack temperature, °F	124.9	125.9	127.1	124.5	125.8
Isokinetic, %	112.7	106.6	102.2	99.7	101.0
Volume of gas sampled, dscf	33.887	55.073	55.941	55.024	55.483
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	6.617	10.845	10.948	9.563	10.256
Concentration, gr/dscf	0.195	0.197	0.196	0.174	0.185
Emission level, lb/ton	10.50	10.24	10.18	9.12	9.65
Phenolic compounds					
Mass collected, gr	1.782	3.297	3.428	2.897	3.163
Concentration, gr/dscf	0.053	0.060	0.061	0.053	0.057
Emission level, lb/ton	2.83	3.11	3.19	2.76	2.98
Phenol					
Mass collected, gr	0.534	1.120	0.999	1.053	1.026
Concentration, gr/dscf	0.016	0.020	0.018	0.019	0.019
Emission level, lb/ton	0.85	1.06	0.93	1.00	0.97
Formaldehyde					
Mass collected, gr	0.959	1.716	1.745	1.671	1.708
Concentration, gr/dscf	0.028	0.031	0.031	0.030	0.031
Emission level, lb/ton	1.52	1.62	1.62	1.59	1.61

*Data excluded from average.
N/A = Not applicable.

TABLE C-25b. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Forming
Product: R-11 Building Insulation
(Metric)

Run number:	1*	2*	3	4	Avg.
Date	04/13/81	04/13/81	04/13/81	04/13/81	--
Sampling time, min	72	68	72	72	--
Glass pull rate, % of design	106	106	106	106	--
Moisture, % by volume	15.05	15.68	15.75	14.29	15.02
Avg. stack temperture, °C	51.6	52.1	52.8	51.4	52.1
Isokinetic, %	112.7	106.6	102.2	99.7	101.0
Volume of gas sampled, Nm^3	0.960	1.559	1.584	1.558	1.571
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	429.70	704.20	710.90	621.00	665.95
Concentration, mg/Nm^3	446.86	450.61	447.84	397.73	422.79
Emission level, kg/Mg	5.25	5.12	5.09	4.56	4.83
Phenolic compounds					
Mass collected, mg	115.70	214.10	222.60	188.10	205.35
Concentration, mg/Nm^3	120.32	137.00	140.23	120.47	130.35
Emission level, kg/Mg	1.42	1.56	1.60	1.38	1.49
Phenol					
Mass collected, mg	34.70	72.70	64.90	68.40	66.65
Concentration, mg/Nm^3	36.09	46.52	40.88	43.81	42.35
Emission level, kg/Mg	0.43	0.53	0.47	0.50	0.49
Formaldehyde					
Mass collected, mg	62.30	111.40	113.30	108.50	110.90
Concentration, mg/Nm^3	64.79	71.28	71.37	69.49	70.43
Emission level, kg/Mg	0.76	0.81	0.81	0.80	0.81

*Data excluded from average.
N/A = Not applicable.

TABLE C-26a. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Dry ESP Outlet Product: R-11 Building Insulation
(English)

Run number:	1*	2B*	3	4	5	6	7	Avg.
Date	04/07/81	04/08/81	04/09/81	04/10/81	04/10/81	04/11/81	04/14/81	--
Sampling time, min	160	80	160	160	160	160	160	--
Glass pull rate, % of design	107	105	103	107	107	105	105	--
Moisture, % by volume	31.63	28.56	32.42	31.51	31.54	31.56	31.12	31.63
Avg. stack temperature, °F	571.4	575.1	574.3	576.9	584.3	580.3	583.6	579.9
Isokinetic, %	110.3	95.8	105.3	105.3	96.1	105.1	101.8	102.7
Volume of gas sampled, dscf	61.245	25.551	51.799	51.773	49.381	53.773	41.806	49.706
Opacity average, %	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--
Particulate matter								
Mass collected, gr	6.754	1.666	2.593	2.102	2.170	3.040	1.555	2.292
Concentration, gr/dscf	0.110	0.065	0.050	0.041	0.044	0.057	0.037	0.046
Emission level, lb/ton	1.56	0.91	0.65	0.51	0.58	0.74	0.53	0.60
Phenolic compounds								
Mass collected, gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Concentration, gr/dscf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emission level, lb/ton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenol								
Mass collected, gr	0.054	0.0	0.0	0.021	0.0	0.0	0.0	0.0
Concentration, gr/dscf	0.001	0.0	0.0	0.000	0.0	0.0	0.0	0.0
Emission level, lb/ton	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.0
Formaldehyde								
Mass collected, gr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Concentration, gr/dscf	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emission level, lb/ton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*Data excluded from average.
N/A = Not applicable.

TABLE C-26b. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Dry ESP Outlet Product: R-11 Building Insulation
(Metric)

Run number:	1*	2B*	3	4	5	6	7	Avg.
Date	04/07/81	04/08/81	04/09/81	04/10/81	04/10/81	04/11/81	04/14/81	--
Sampling time, min	160	80	160	160	160	160	160	--
Glass pull rate, % of design	107	105	103	107	107	105	105	--
Moisture, % by volume	31.63	28.56	32.42	31.51	31.54	31.56	31.12	31.63
Avg. stack temperature, °C	299.7	301.7	301.3	302.7	306.8	304.6	306.5	304.4
Isokinetic, %	110.3	95.8	105.3	105.3	96.1	105.1	101.8	102.7
Volume of gas sampled, Nm^3	1.734	0.723	1.467	1.466	1.398	1.523	1.184	1.408
Opacity average, %	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--
Particulate matter								
Mass collected, mg	438.60	108.20	168.40	136.50	140.90	197.40	101.00	148.84
Concentration, mg/Nm^3	252.37	149.24	114.57	92.91	100.55	129.37	85.14	104.51
Emission level, kg/Mg	0.78	0.46	0.33	0.26	0.29	0.37	0.27	0.30
Phenolic compounds								
Mass collected, mg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Concentration, mg/Nm^3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emission level, kg/Mg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Phenol								
Mass collected, mg	3.60	0.0	0.0	1.40	0.0	0.0	0.0	0.28
Concentration, mg/Nm^3	2.07	0.0	0.0	0.95	0.0	0.0	0.0	0.19
Emission level, kg/Mg	0.01	0.0	0.0	0.01	0.0	0.0	0.0	0.0
Formaldehyde								
Mass collected, mg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Concentration, mg/Nm^3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Emission level, kg/Mg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*Data excluded from average.
N/A = Not applicable.

TABLE C-27a. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Combined ESP Breeching Product: R-11 Building Insulation
(English)

Run number:	1*	1B*	2A*	2B*	3A*	4A	4B	5A	5B	6B*	7B	Avg.
Date	04/07/81	04/07/81	04/08/81	04/08/81	04/09/81	04/10/81	04/10/81	04/10/81	04/10/81	04/11/81	04/14/81	--
Sampling time, min	128	128	128	128	128	128	128	128	128	128	128	--
Glass pull rate, % of design	107	107	105	105	103	107	107	107	107	105	105	--
Moisture, % by volume	13.35	12.20	13.00	12.43	13.25	14.28	14.04	14.51	14.40	13.48	15.43	14.53
Avg. stack temperature, °F	168.3	174.5	169.2	169.8	167.2	180.1	180.2	180.5	178.5	176.9	182.6	180.4
Isokinetic, %	108.7	127.4	99.2	112.1	98.0	106.8	106.7	99.7	106.0	116.3	103.1	104.5
Volume of gas sampled, dscf	80.783	85.074	75.913	76.059	70.438	67.053	60.389	64.009	61.263	65.667	57.126	61.968
Opacity average, %	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--
Particulate matter												
Mass collected, gr	2.347	2.134	1.954	1.814	1.774	1.589	1.411	1.777	1.535	1.397	2.604	1.783
Concentration, gr/dscf	0.029	0.025	0.026	0.024	0.025	0.024	0.023	0.028	0.025	0.021	0.046	0.029
Emission level, lb/ton	4.00	3.39	3.71	3.33	3.46	2.75	2.68	3.30	2.93	2.46	5.19	3.37
Phenolic compounds												
Mass collected, gr	0.853	0.836	0.845	0.785	0.593	0.578	0.570	0.548	0.510	0.454	0.719	0.585
Concentration, gr/dscf	0.011	0.010	0.011	0.010	0.008	0.009	0.009	0.009	0.008	0.007	0.013	0.010
Emission level, lb/ton	1.45	1.33	1.61	1.44	1.15	1.00	1.08	1.02	0.97	0.80	1.43	1.10
Phenol												
Mass collected, gr	0.574	0.693	0.598	0.556	0.417	0.396	0.388	0.422	0.394	0.328	0.473	0.415
Concentration, gr/dscf	0.007	0.008	0.008	0.007	0.006	0.006	0.006	0.007	0.006	0.005	0.008	0.007
Emission level, lb/ton	0.98	1.10	1.14	1.02	0.81	0.69	0.74	0.78	0.75	0.58	0.94	0.78
Formaldehyde												
Mass collected, gr	0.291	0.288	0.217	0.177	0.225	0.240	0.220	0.232	0.243	0.231	0.248	0.237
Concentration, gr/dscf	0.004	0.003	0.003	0.002	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Emission level, lb/ton	0.50	0.46	0.41	0.33	0.44	0.42	0.42	0.43	0.46	0.41	0.49	0.44

*Data excluded from average.
N/A = Not applicable.

TABLE C-27b. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Combined ESP Breeching Product: R-11 Building Insulation
(Metric)

Run number:	1*	1B*	2A*	2B*	3A*	4A	4B	5A	5B	6B*	7B	Avg
Date	04/07/81	04/07/81	04/08/81	04/08/81	04/09/81	04/10/81	04/10/81	04/10/81	04/10/81	04/11/81	04/14/81	--
Sampling time, min	128	128	128	128	128	128	128	128	128	128	128	--
Glass pull rate, % of design	107	107	105	105	103	107	107	107	107	105	105	--
Moisture, % by volume	13.35	12.20	13.00	12.43	13.25	14.28	14.04	14.51	14.40	13.48	15.43	14.53
Avg. stack temperature, °C	75.7	79.2	76.2	76.6	75.1	82.3	82.3	82.5	81.4	80.5	83.7	82.4
Isokinetic, %	108.7	127.4	99.2	112.1	98.0	106.8	106.7	99.7	106.0	116.3	103.1	104.5
Volume of gas sampled, Nm^3	2.287	2.409	2.150	2.154	1.995	1.899	1.710	1.812	1.735	1.859	1.618	1.755
Opacity average, %	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	--
Particulate matter												
Mass collected, mg	152.40	138.60	126.90	117.80	115.20	103.20	91.60	115.40	99.70	90.70	169.10	115.80
Concentration, mg/Nm^3	66.48	57.41	58.91	54.58	57.64	54.24	33.45	63.54	57.35	48.67	104.32	66.58
Emission level, kg/Mg	2.00	1.20	1.86	1.67	1.73	1.38	1.34	1.65	1.47	1.23	2.60	1.69
Phenolic compounds												
Mass collected, mg	55.40	54.30	54.90	51.00	38.50	37.50	37.00	35.60	33.10	29.50	46.70	37.98
Concentration, mg/Nm^3	24.17	22.49	25.49	23.63	19.26	19.71	21.59	19.60	19.04	15.83	28.81	21.75
Emission level, kg/Mg	0.73	0.67	0.81	0.72	0.58	0.50	0.54	0.51	0.49	0.40	0.72	0.55
Phenol												
Mass collected, mg	37.30	45.00	38.80	36.10	27.10	25.70	25.20	27.40	25.60	21.30	30.70	26.92
Concentration, mg/Nm^3	16.27	18.64	18.01	16.73	13.56	13.51	14.71	15.09	14.73	11.43	18.94	15.40
Emission level, kg/Mg	0.49	0.55	0.57	0.51	0.41	0.35	0.37	0.39	0.38	0.29	0.47	0.39
Formaldehyde												
Mass collected, mg	18.90	18.70	14.10	11.50	14.60	15.60	14.30	15.10	15.80	15.00	16.10	15.38
Concentration, mg/Nm^3	8.25	7.75	6.55	5.33	7.31	8.20	8.35	8.31	9.09	8.05	9.93	8.78
Emission level, kg/Mg	0.25	0.23	0.21	0.17	0.22	0.21	0.21	0.22	0.23	0.21	0.25	0.22

*Data excluded from average.
N/A = Not applicable.

TABLE C-28a. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Cooling
Product: R-11 Building Insulation
(English)

Run number:	1A	2	3	Avg.
Date	04/13/81	04/13/81	04/13/81	--
Sampling time, min	147	98	98	--
Glass pull rate, % of design	106	106	106	--
Moisture, % by volume	10.37	10.78	9.95	10.37
Avg. stack temperature, °F	108.4	107.6	107.4	107.8
Isokinetic, %	96.0	96.6	99.2	97.3
Volume of gas sampled, dscf	91.931	64.018	59.656	71.868
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	8.271	4.361	3.630	5.421
Concentration, gr/dscf	0.090	0.068	0.061	0.073
Emission level, lb/ton	0.76	0.60	0.49	0.62
Phenolic compounds				
Mass collected, gr	1.197	0.853	0.802	0.951
Concentration, gr/dscf	0.013	0.013	0.013	0.013
Emission level, lb/ton	0.11	0.12	0.11	0.11
Phenol				
Mass collected, gr	0.661	0.467	0.433	0.520
Concentration, gr/dscf	0.007	0.007	0.007	0.007
Emission level, lb/ton	0.06	0.06	0.06	0.06
Formaldehyde				
Mass collected, gr	0.798	0.467	0.548	0.604
Concentration, gr/dscf	0.009	0.007	0.009	0.008
Emission level, lb/ton	0.07	0.06	0.07	0.07

N/A = Not applicable.

TABLE C-28b. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Cooling
Product: R-11 Building Insulation
(Metric)

Run number:	1A	2	3	Avg.
Date	04/13/81	04/13/81	04/13/81	--
Sampling time, min	147	98	98	--
Glass pull rate, % of design	106	106	106	--
Moisture, % by volume	10.37	10.78	9.95	10.37
Avg. stack temperture, °C	42.4	42.0	41.9	42.1
Isokinetic, %	96.0	96.6	99.2	97.3
Volume of gas sampled, Nm^3	2.603	1.813	1.689	2.035
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	537.10	283.20	235.70	352.00
Concentration, mg/Nm^3	205.89	155.90	139.24	167.01
Emission level, kg/Mg	0.38	0.30	0.25	0.31
Phenolic compounds				
Mass collected, mg	77.70	55.40	52.10	61.73
Concentration, mg/Nm^3	29.79	30.50	30.78	30.36
Emission level, kg/Mg	0.06	0.06	0.06	0.06
Phenol				
Mass collected, mg	42.90	30.30	28.10	33.77
Concentration, mg/Nm^3	16.45	16.68	16.50	16.58
Emission level, kg/Mg	0.03	0.03	0.03	0.03
Formaldehyde				
Mass collected, mg	51.80	30.30	35.60	39.23
Concentration, mg/Nm^3	19.86	16.68	21.03	19.19
Emission level, kg/Mg	0.04	0.03	0.04	0.04

N/A = Not applicable.

TABLE C-29a. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Asphalt
Product: R-11 Building Insulation
(English)

Run number:	1A*	2	3*	Avg.
Date	04/13/81	04/13/81	04/13/81	--
Sampling time, min	96	96	96	--
Glass pull rate, % of design	106	106	106	--
Moisture, % by volume	1.46	1.81	1.41	1.81
Avg. stack temperature, °F	85.3	90.9	88.0	90.9
Isokinetic, %	91.3	93.6	94.8	93.6
Volume of gas sampled, dscf	78.342	79.064	90.125	79.064
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	0.342[a]	0.516	0.223[a]	0.516
Concentration, gr/dscf	0.004[a]	0.007	0.003[a]	0.007
Emission level, lb/ton	0.02[a]	0.04	0.02[a]	0.04
Phenolic compounds				
Mass collected, gr	0.003	0.009	0.005	0.009
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.00	0.00
Phenol				
Mass collected, gr	0.003	0.009	0.005	0.009
Concentration, gr/dscf	0.000	0.000	0.000	0.00
Emission level, lb/ton	0.00	0.00	0.00	0.00
Formaldehyde				
Mass collected, gr	0.0	0.0	0.0	0.0
Concentration, gr/dscf	0.0	0.0	0.0	0.0
Emission level, lb/ton	0.0	0.0	0.0	0.0

*Data excluded from average.

[a] Values are for front-half catch only; insufficient sample for analysis of back-half catch.

N/A = Not applicable.

TABLE C-29b. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Asphalt
Product: R-11 Building Insulation
(Metric)

Run number:	1A*	2	3*	Avg.
Date	04/13/81	04/13/81	04/13/81	--
Sampling time, min	96	96	96	--
Glass pull rate, % of design	106	106	106	--
Moisture, % by volume	1.46	1.81	1.41	1.81
Avg. stack temperture, °C	29.6	32.7	31.1	32.7
Isokinetic, %	91.3	93.6	94.8	93.6
Volume of gas sampled, Nm^3	2.218	2.239	2.552	2.239
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	22.20[a]	33.50	14.50[a]	33.50
Concentration, mg/Nm^3	9.99[a]	14.93	5.67[a]	14.93
Emission level, kg/Mg	0.01[a]	0.02	0.01[a]	0.02
Phenolic compounds				
Mass collected, mg	0.20	0.60	0.30	0.60
Concentration, mg/Nm^3	0.09	0.27	0.12	0.27
Emission level, kg/Mg	0.00	0.00	0.00	0.00
Phenol				
Mass collected, mg	0.20	0.60	0.30	0.60
Concentration, mg/Nm^3	0.090	0.27	0.12	0.27
Emission level, kg/Mg	0.00	0.00	0.00	0.00
Formaldehyde				
Mass collected, mg	0.0	0.0	0.0	0.0
Concentration, mg/Nm^3	0.0	0.0	0.0	0.0
Emission level, kg/Mg	0.0	0.0	0.0	0.0

*Data excluded from average.

[a] Values are for front-half catch only; insufficent sample for analysis of back-half catch.

N/A = Not applicable.

TABLE C-30a. SUMMARY OF TEST RESULTS--LINE D
Sampling Location: Combined Asphalt, Cooling and Curing
Product: R-11 Building Insulation
(English)

Run number:	1	2	3*	4	Avg.
Date	04/13/81	04/13/81	04/13/81	04/14/81	--
Sampling time, min	96	96	96	96	--
Glass pull rate, % of design	106	106	106	105	--
Moisture, % by volume	8.41	8.65	7.29	8.01	8.36
Avg. stack temperature, °F	107.8	107.9	106.4	104.9	106.9
Isokinetic, %	104.8	102.6	99.1	97.1	101.5
Volume of gas sampled, dscf	60.526	59.831	61.193	58.720	59.692
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	2.977	2.459	2.227	2.895	2.777
Concentration, gr/dscf	0.049	0.041	0.036	0.049	0.046
Emission level, lb/ton	2.13	1.79	1.62	2.16	2.03
Phenolic compounds					
Mass collected, gr	0.607	0.588	0.590	0.667	0.621
Concentration, gr/dscf	0.010	0.010	0.010	0.011	0.010
Emission level, lb/ton	0.43	0.43	0.43	0.49	0.45
Phenol					
Mass collected, gr	0.125	0.226	0.174	0.303	0.218
Concentration, gr/dscf	0.002	0.004	0.003	0.005	0.004
Emission level, lb/ton	0.09	0.17	0.13	0.22	0.16
Formaldehyde					
Mass collected, gr	0.484	0.348	0.465	0.333	0.388
Concentration, gr/dscf	0.008	0.006	0.008	0.006	0.007
Emission level, lb/ton	0.35	0.25	0.34	0.25	0.28

*Data excluded from average.
N/A = Not applicable.

TABLE C-30b. SUMMARY OF TEST RESULTS--LINE D

Sampling Location: Combined Asphalt, Cooling and Curing
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3*	4	Avg.
Date	04/13/81	04/13/81	04/13/81	04/14/81	--
Sampling time, min	96	96	96	96	--
Glass pull rate, % of design	106	106	106	105	--
Moisture, % by volume	8.41	8.65	7.29	8.01	8.36
Avg. stack temperture, °C	42.1	42.2	41.4	40.5	41.6
Isokinetic, %	104.8	102.6	99.1	97.1	101.5
Volume of gas sampled, Nm^3	1.714	1.694	1.733	1.663	1.690
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	193.30	159.70	144.60	188.00	180.33
Concentration, mg/Nm^3	112.55	94.06	83.28	112.83	106.48
Emission level, kg/Mg	1.07	0.90	0.81	1.08	1.02
Phenolic compounds					
Mass collected, mg	39.40	38.20	38.30	43.30	40.3
Concentration, mg/Nm^3	22.94	22.50	22.06	25.99	23.81
Emission level, kg/Mg	0.22	0.22	0.22	0.25	0.23
Phenol					
Mass collected, mg	8.10	14.70	11.30	19.70	14.17
Concentration, mg/Nm^3	4.72	8.66	6.51	11.82	8.40
Emission level, kg/Mg	0.05	0.09	0.07	0.11	0.08
Formaldehyde					
Mass collected, mg	31.40	22.60	30.20	21.60	25.20
Concentration, mg/Nm^3	18.28	13.31	17.39	12.96	14.85
Emission level, kg/Mg	0.18	0.13	0.17	0.13	0.15

*Data excluded from average.
N/A = Not applicable.

TABLE C-31a. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Wet ESP Inlet Without Water Sprays
Product: Ductboard
(English)

Run number:	1*	2*	3*	4	Avg.
Date	09/09/81	09/091/81	09/10/81	09/10/81	--
Sampling time, min	150	100	100	100	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	4.36	5.81	5.57	5.65	5.65
Avg. stack temperature, °F	93.7	95.3	93.6	94.1	94.1
Isokinetic, %	98.1	102.1	97.6	98.1	98.1
Volume of gas sampled, dscf	72.834	49.935	47.051	46.998	46.998
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	7.295	6.160	7.380	7.183	7.183
Concentration, gr/dscf	0.100	0.123	0.157	0.153	0.153
Emission level, lb/ton	34.92	42.50	53.26	51.60	51.60
Phenolic compounds					
Mass collected, gr	2.347	2.255	2.871	2.626	2.626
Concentration, gr/dscf	0.032	0.045	0.061	0.056	0.056
Emission level, lb/ton	11.24	15.55	20.72	18.86	18.86
Phenol					
Mass collected, gr	0.966	1.050	1.152	1.160	1.160
Concentration, gr/dscf	0.013	0.021	0.025	0.025	0.025
Emission level, lb/ton	4.62	7.25	8.31	8.33	8.33
Formaldehyde					
Mass collected, gr	0.581	0.619	0.800	0.630	0.630
Concentration, gr/dscf	0.008	0.012	0.017	0.013	0.013
Emission level, lb/ton	2.78	4.27	5.78	4.52	4.52

*Data excluded from average.
N/A = Not applicable.

TABLE C-31b. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Wet ESP Inlet Without Water Sprays
Product: Ductboard
(Metric)

Run number:	1*	2*	3*	4	Avg.
Date	09/09/81	09/09/81	09/10/81	09/10/81	--
Sampling time, min	150	100	100	100	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	4.36	5.81	5.57	5.65	5.65
Avg. stack temperture, °C	34.3	35.2	34.2	34.5	34.5
Isokinetic, %	98.1	102.1	97.6	98.1	98.1
Volume of gas sampled, Nm^3	2.062	1.414	1.332	1.331	1.331
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	473.70	400.00	479.20	466.40	466.40
Concentration, mg/Nm^3	229.20	282.29	358.92	349.72	349.72
Emission level, kg/Mg	17.46	21.25	26.63	25.80	25.80
Phenolic compounds					
Mass collected, mg	152.40	146.40	186.40	170.50	170.50
Concentration, mg/Nm^3	73.74	103.32	139.61	127.85	127.85
Emission level, kg/Mg	5.62	7.78	10.36	9.43	9.43
Phenol					
Mass collected, mg	62.70	68.20	74.80	75.30	75.30
Concentration, mg/Nm^3	30.34	48.13	56.03	56.46	56.46
Emission level, kg/Mg	2.31	3.63	4.16	4.17	4.17
Formaldehyde					
Mass collected, mg	37.70	40.20	52.00	40.90	40.90
Concentration, mg/Nm^3	18.24	28.37	38.95	30.67	30.67
Emission level, kg/Mg	1.39	2.14	2.89	2.26	2.26

*Data excluded from average.
N/A = Not applicable.

TABLE C-32a. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Wet ESP Inlet With Water Sprays
Product: Ductboard
(English)

Run number:	5	6	7	Avg.
Date	09/11/81	09/11/81	09/11/81	--
Sampling time, min	100	98	100	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	5.08	6.03	6.45	5.85
Avg. stack temperature, °F	89.7	95.3	97.2	94.1
Isokinetic, %	95.4	93.7	93.2	94.1
Volume of gas sampled, dscf	47.755	43.970	50.253	47.326
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	69.238	70.620	102.872	80.910
Concentration, gr/dscf	1.450	1.610	2.050	1.703
Emission level, lb/ton	511.28	541.77	777.67	610.24
Phenolic compounds				
Mass collected, gr	15.352	17.313	25.080	19.248
Concentration, gr/dscf	0.321	0.394	0.499	0.405
Emission level, lb/ton	113.37	132.82	189.60	145.26
Phenol				
Mass collected, gr	2.627	2.647	3.108	2.794
Concentration, gr/dscf	0.055	0.060	0.062	0.059
Emission level, lb/ton	19.40	20.31	23.49	21.07
Formaldehyde				
Mass collected, gr	3.533	4.374	6.120	4.676
Concentration, gr/dscf	0.074	0.100	0.122	0.099
Emission level, lb/ton	26.09	33.55	46.26	35.30

N/A = Not applicable.

TABLE C-32b. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Wet ESP Inlet With Water Sprays
Product: Ductboard
(Metric)

Run number:	5	6	7	Avg.
Date	09/11/81	09/11/81	09/11/81	--
Sampling time, min	100	98	100	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	5.08	6.03	6.45	5.85
Avg. stack temperture, °C	32.1	35.2	36.2	34.5
Isokinetic, %	95.4	93.7	93.2	94.1
Volume of gas sampled, Nm^3	1.352	1.245	1.423	1.340
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	4,496.00	4,585.70	6,680.00	5,253.90
Concentration, mg/Nm^3	3,317.82	3,675.32	4,684.41	3,892.52
Emission level, kg/Mg	255.64	270.89	388.84	305.12
Phenolic compounds				
Mass collected, mg	996.90	1,124.20	1,628.60	1,249.90
Concentration, mg/Nm^3	735.66	901.02	1,142.07	926.25
Emission level, kg/Mg	56.69	66.41	94.80	72.63
Phenol				
Mass collected, mg	170.60	171.90	201.80	181.43
Concentration, mg/Nm^3	125.89	137.77	141.51	135.06
Emission level, kg/Mg	9.70	10.16	11.75	10.54
Formaldehyde				
Mass collected, mg	229.40	284.00	397.40	303.60
Concentration, mg/Nm^3	162.29	227.62	278.68	225.20
Emission level, kg/Mg	13.05	16.78	23.13	17.65

N/A = Not applicable.

TABLE C-33a. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Wet ESP Outlet With Water Sprays
Product: Ductboard
(English)

Run number:	1*	2*	3*	Avg.
Date	09/11/81	09/11/81	09/11/81	--
Sampling time, min	105	102	105	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	6.82	6.86	7.15	--
Avg. stack temperature, °F	100.0	101.2	101.3	--
Isokinetic, %	102.3	98.7	99.6	--
Volume of gas sampled, dscf	74.478	70.257	74.428	--
Opacity average, %	--	--	--	--
Particulate matter				
Mass collected, gr	3.588	4.198	4.030	--
Concentration, gr/dscf	0.048	0.060	0.054	--
Emission level, lb/ton	15.05	18.77	17.35	--
Phenolic compounds				
Mass collected, gr	2.415	2.704	2.817	--
Concentration, gr/dscf	0.032	0.039	0.038	--
Emission level, lb/ton	10.13	12.09	12.13	--
Phenol				
Mass collected, gr	1.990	1.939	2.005	--
Concentration, gr/dscf	0.027	0.028	0.027	--
Emission level, lb/ton	8.34	8.67	8.63	--
Formaldehyde				
Mass collected, gr	0.174	0.311	0.838	--
Concentration, gr/dscf	0.002	0.004	0.011	--
Emission level, lb/ton	0.73	1.39	3.61	--

*Data excluded.

TABLE C-33b. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Wet ESP Outlet With Water Sprays
Product: Ductboard
(Metric)

Run number:	1*	2*	3*	Avg.
Date	09/11/81	09/11/81	09/11/81	--
Sampling time, min	105	102	105	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	6.82	6.86	7.15	--
Avg. stack temperture, °C	37.8	38.5	38.5	--
Isokinetic, %	102.3	98.7	99.6	--
Volume of gas sampled, Nm^3	2.109	1.989	2.108	--
Opacity average, %	--	--	--	--
Particulate matter				
Mass collected, mg	233.00	272.60	261.70	--
Concentration, mg/Nm^3	110.25	136.74	123.91	--
Emission level, kg/Mg	7.53	9.39	8.68	--
Phenolic compounds				
Mass collected, mg	156.80	175.60	182.90	--
Concentration, mg/Nm^3	74.19	86.08	86.60	--
Emission level, kg/Mg	5.07	6.05	6.07	--
Phenol				
Mass collected, mg	129.20	125.90	130.20	--
Concentration, mg/Nm^3	61.13	63.15	61.65	--
Emission level, kg/Mg	4.17	4.34	4.32	--
Formaldehyde				
Mass collected, mg	11.30	20.20	54.40	--
Concentration, mg/Nm^3	5.35	10.13	25.76	--
Emission level, kg/Mg	0.37	0.70	1.81	--

*Data excluded.

TABLE C-34a. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Forming
Product: Ductboard
(English)

Run number:	1	2	3	4	Avg.
Date	09/09/81	09/09/81	09/10/81	09/10/81	--
Sampling time, min	144	95	96	96	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	6.56	6.26	6.09	7.37	6.57
Avg. stack temperature, °F	99.2	104.5	104.7	105.7	103.5
Isokinetic, %	99.3	101.1	100.8	104.5	101.4
Volume of gas sampled, dscf	64.304	42.806	43.706	45.304	49.030
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	6.385	4.748	5.737	5.733	5.651
Concentration, gr/dscf	0.099	0.111	0.131	0.127	0.117
Emission level, lb/ton	20.75	22.98	27.55	26.56	24.46
Phenolic compounds					
Mass collected, gr	2.655	1.993	2.472	2.495	2.404
Concentration, gr/dscf	0.041	0.047	0.057	0.055	0.050
Emission level, lb/ton	8.63	9.65	11.87	11.56	10.43
Phenol					
Mass collected, gr	1.500	0.961	1.184	1.058	1.176
Concentration, gr/dscf	0.023	0.022	0.027	0.023	0.024
Emission level, lb/ton	4.87	4.65	5.69	4.90	5.03
Formaldehyde					
Mass collected, gr	0.631	0.558	0.772	0.602	0.641
Concentration, gr/dscf	0.010	0.013	0.018	0.013	0.014
Emission level, lb/ton	2.05	2.70	3.71	2.79	2.81

N/A = Not applicable.

TABLE C-34b. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Forming
Product: Ductboard
(Metric)

Run number:	1	2	3	4	Avg.
Date	09/09/81	09/09/81	09/10/81	09/10/81	--
Sampling time, min	144	95	96	96	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	6.56	6.26	6.09	7.37	6.57
Avg. stack temperture, °C	37.3	40.3	40.4	40.9	39.7
Isokinetic, %	99.3	101.1	100.8	104.5	101.4
Volume of gas sampled, Nm^3	1.821	1.212	1.238	1.283	1.389
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	414.60	308.30	372.50	372.30	366.93
Concentration, mg/Nm^3	227.21	253.81	300.35	289.60	267.74
Emission level, kg/Mg	10.38	11.49	13.78	13.28	12.23
Phenolic compounds					
Mass collected, mg	172.40	129.40	160.50	162.00	156.08
Concentration, mg/Nm^3	94.48	106.53	129.41	126.01	114.11
Emission level, kg/Mg	4.32	4.83	5.94	5.78	5.22
Phenol					
Mass collected, mg	97.40	62.40	76.90	68.70	76.35
Concentration, mg/Nm^3	53.38	51.37	62.01	53.44	55.05
Emission level, kg/Mg	2.44	2.33	2.85	2.45	2.52
Formaldehyde					
Mass collected, mg	41.00	36.20	50.10	39.10	41.60
Concentration, mg/Nm^3	22.47	29.80	40.40	30.42	30.77
Emission level, kg/Mg	1.02	1.35	1.86	1.40	1.41

N/A = Not applicable.

TABLE C-35a. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Cooling
Product: Ductboard
(English)

Run number:	1*	2*	3*	4*	Avg.
Date	09/09/81	09/09/81	09/10/81	09/10/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	1.76	1.90	1.89	1.66	--
Avg. stack temperature, °F	108.0	83.5	78.8	83.4	--
Isokinetic, %	143.6	164.2	208.4	156.7	--
Volume of gas sampled, dscf	27.916	26.631	21.817	25.368	--
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	0.237	0.347	0.323	0.193	--
Concentration, gr/dscf	0.009	0.013	0.015	0.008	--
Emission level, lb/ton	0.01	0.01	0.01	0.01	--
Phenolic compounds					
Mass collected, gr	0.006	0.008	0.011	0.011	--
Concentration, gr/dscf	0.000	0.000	0.000	0.000	--
Emission level, lb/ton	0.00	0.00	0.00	0.00	--
Phenol					
Mass collected, gr	0.048	0.046	0.045	0.028	--
Concentration, gr/dscf	0.002	0.002	0.002	0.001	--
Emission level, lb/ton	0.00	0.00	0.00	0.00	--
Formaldehyde					
Mass collected, gr	0.022	0.035	0.031	0.017	--
Concentration, gr/dscf	0.001	0.001	0.001	0.001	--
Emission level, lb/ton	0.00	0.00	0.00	0.00	--

*Data excluded.
N/A = Not applicable.

TABLE C-35b. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Cooling
Product: Ductboard
(Metric)

Run number:	1*	2*	3*	4*	Avg.
Date	09/09/81	09/09/81	09/10/81	09/10/81	--
Sampling time, min	144	144	144	144	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	1.76	1.90	1.89	1.66	--
Avg. stack temperture, °C	42.2	28.6	26.0	28.6	--
Isokinetic, %	143.6	164.2	208.4	156.7	--
Volume of gas sampled, Nm^3	0.790	0.754	0.618	0.718	--
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	15.40	22.50	21.00	12.50	--
Concentration, mg/Nm^3	19.44	29.77	33.92	17.37	--
Emission level, kg/Mg	0.01	0.01	0.01	0.01	--
Phenolic compounds					
Mass collected, mg	0.40	0.50	0.70	0.70	--
Concentration, mg/Nm^3	0.51	0.66	1.13	0.97	--
Emission level, kg/Mg	0.00	0.00	0.00	0.00	--
Phenol					
Mass collected, mg	3.10	3.00	2.90	1.80	--
Concentration, mg/Nm^3	3.91	3.97	4.68	2.50	--
Emission level, kg/Mg	0.00	0.00	0.00	0.00	--
Formaldehyde					
Mass collected, mg	1.40	2.30	2.00	1.10	--
Concentration, mg/Nm^3	1.77	3.04	3.23	1.53	--
Emission level, kg/Mg	0.00	0.00	0.00	0.00	--

*Data excluded.
N/A = Not applicable.

TABLE C-36a. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Asphalt
Product: Ductboard
(English)

Run number:	A1	A2	A3	A4*	Avg.
Date	09/09/81	09/09/81	09/10/81	09/10/81	--
Sampling time, min	140	100	100	100	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	1.39	0.41	1.60	2.11	1.13
Avg. stack temperature, °F	64.8	65.1	66.3	71.2	65.4
Isokinetic, %	95.0	105.9	105.8	110.3	102.2
Volume of gas sampled, dscf	63.247	51.136	43.497	45.326	52.627
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	0.336	0.286	0.223	0.260	0.285
Concentration, gr/dscf	0.005	0.006	0.005	0.006	0.005
Emission level, lb/ton	0.03	0.03	0.02	0.02	0.03
Phenolic compounds					
Mass collected, gr	0.049	0.035	0.035	0.048	0.040
Concentration, gr/dscf	0.001	0.001	0.001	0.001	0.001
Emission level, lb/ton	0.00	0.00	0.00	0.00	0.00
Phenol					
Mass collected, gr	0.091	0.089	0.099	0.097	0.093
Concentration, gr/dscf	0.001	0.002	0.002	0.002	0.002
Emission level, lb/ton	0.01	0.01	0.01	0.01	0.01
Formaldehyde					
Mass collected, gr	0.014	0.017	0.019	0.014	0.017
Concentration, gr/dscf	0.000	0.000	0.000	0.000	0.000
Emission level, lb/tun	0.00	0.00	0.00	0.00	0.00

*Data excluded from average.
N/A = Not applicable.

TABLE C-36b. SUMMARY OF TEST RESULTS--LINE E
Sampling Location: Asphalt
Product: Ductboard
(Metric)

Run number:	A1	A2	A3	A4*	Avg.
Date	09/09/81	09/09/81	09/10/81	09/10/81	--
Sampling time, min	140	100	100	100	--
Glass pull rate, % of design	102	102	102	102	--
Moisture, % by volume	1.39	0.41	1.60	2.11	1.13
Avg. stack temperture, °C	18.2	18.4	19.1	21.8	19.375
Isokinetic, %	95.0	105.9	105.8	110.3	102.2
Volume of gas sampled, Nm^3	1.791	1.448	1.232	1.283	1.439
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	21.80	18.60	14.50	16.90	18.30
Concentration, mg/Nm^3	12.15	12.82	11.75	13.14	12.24
Emission level, kg/Mg	0.02	0.02	0.01	0.01	0.02
Phenolic compounds					
Mass collected, mg	3.20	2.30	2.30	3.10	2.60
Concentration, mg/Nm^3	1.78	1.59	1.86	2.41	1.74
Emission level, kg/Mg	0.00	0.00	0.00	0.00	0.00
Phenol					
Mass collected, mg	5.90	5.80	6.40	6.30	6.03
Concentration, mg/Nm^3	3.29	4.00	5.19	4.90	4.16
Emission level, kg/Mg	0.01	0.01	0.01	0.01	0.01
Formaldehyde					
Mass collected, mg	0.90	1.10	1.20	0.90	1.07
Concentration, mg/Nm^3	0.50	0.76	0.97	0.70	0.74
Emission level, kg/Mg	0.00	0.00	0.00	0.00	0.00

*Data excluded from average.
N/A = Not applicable.

TABLE C-37a. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Forming North
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	4.95	5.25	4.96	5.05
Avg. stack temperature, °F	134.4	132.4	139.4	135.4
Isokinetic, %	102.4	101.3	98.5	100.7
Volume of gas sampled, dscf	70.371	66.941	66.267	67.860
Opacity average, %	10	10	10	--
Particulate matter				
Mass collected, gr	3.405	2.997	3.242	3.215
Concentration, gr/dscf	0.048	0.045	0.049	0.047
Emission level, lb/ton	3.54	3.10	3.43	3.36
Phenolic compounds				
Mass collected, gr	0.959	0.882	0.861	0.901
Concentration, gr/dscf	0.014	0.013	0.013	0.013
Emission level, lb/ton	1.00	0.91	0.91	0.94
Phenol				
Mass collected, gr	0.571	0.530	0.410	0.504
Concentration, gr/dscf	0.008	0.008	0.006	0.007
Emission level, lb/ton	0.59	0.55	0.43	0.52
Formaldehyde				
Mass collected, gr	0.291	0.276	0.393	0.320
Concentration, gr/dscf	0.004	0.004	0.006	0.005
Emission level, lb/ton	0.30	0.29	0.42	0.33

TABLE C-37b. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Forming North
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	4.95	5.25	4.96	5.05
Avg. stack temperture, °C	56.9	55.8	59.7	57.5
Isokinetic, %	102.4	101.3	98.5	100.7
Volume of gas sampled, Nm^3	1.993	1.896	1.876	1.922
Opacity average, %	10	10	10	--
Particulate matter				
Mass collected, mg	221.10	194.60	210.50	208.73
Concentration, mg/Nm^3	110.72	102.45	111.94	108.37
Emission level, kg/Mg	1.77	1.55	1.72	1.68
Phenolic compounds				
Mass collected, mg	62.30	57.30	55.90	58.50
Concentration, mg/Nm^3	31.20	30.17	29.73	30.37
Emission level, kg/Mg	0.50	0.46	0.46	0.47
Phenol				
Mass collected, mg	37.10	34.40	26.60	32.70
Concentration, mg/Nm^3	18.58	18.11	14.15	16.95
Emission level, kg/Mg	0.30	0.28	0.22	0.27
Formaldehyde				
Mass collected, mg	18.90	17.90	25.50	20.77
Concentration, mg/Nm^3	9.47	9.42	13.56	10.82
Emission level, kg/Mg	0.15	0.15	0.21	0.17

TABLE C-38a. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Forming Middle
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	126	126	123	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	4.06	4.22	4.65	4.31
Avg. stack temperature, °F	130.2	116.8	126.7	124.6
Isokinetic, %	99.9	99.9	100.0	99.9
Volume of gas sampled, dscf	81.738	83.629	85.428	83.598
Opacity average, %	5	5	5	--
Particulate matter				
Mass collected, gr	2.405	3.343	3.459	3.069
Concentration, gr/dscf	0.029	0.040	0.041	0.037
Emission level, lb/ton	2.54	3.48	3.66	3.23
Phenolic compounds				
Mass collected, gr	0.930	0.907	0.872	0.903
Concentration, gr/dscf	0.011	0.011	0.010	0.011
Emission level, lb/ton	0.98	0.94	0.92	0.95
Phenol				
Mass collected, gr	0.553	0.530	0.445	0.509
Concentration, gr/dscf	0.007	0.006	0.005	0.006
Emission level, lb/ton	0.58	0.55	0.47	0.53
Formaldehyde				
Mass collected, gr	0.285	0.363	0.356	0.335
Concentration, gr/dscf	0.004	0.004	0.004	0.004
Emission level, lb/ton	0.30	0.38	0.38	0.35

TABLE C-38b. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Forming Middle
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	126	126	123	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	4.06	4.22	4.65	4.31
Avg. stack temperture, °C	54.5	47.1	52.6	51.4
Isokinetic, %	99.9	99.9	100.0	99.9
Volume of gas sampled, Nm^3	2.314	2.368	2.419	2.367
Opacity average, %	5	5	5	--
Particulate matter				
Mass collected, mg	156.20	217.10	224.60	199.30
Concentration, mg/Nm^3	67.34	91.49	92.65	83.83
Emission level, kg/Mg	1.27	1.74	1.83	1.61
Phenolic compounds				
Mass collected, mg	60.40	58.90	56.60	58.63
Concentration, mg/Nm^3	26.04	24.82	23.35	24.74
Emission level, kg/Mg	0.49	0.47	0.46	0.47
Phenol				
Mass collected, mg	35.90	34.40	28.90	33.07
Concentration, mg/Nm^3	15.48	14.50	11.92	13.97
Emission level, kg/Mg	0.29	0.28	0.24	0.27
Formaldehyde				
Mass collected, mg	18.50	23.60	23.10	21.73
Concentration, mg/Nm^3	7.98	9.95	9.53	9.15
Emission level, kg/Mg	0.15	0.19	0.19	0.18

TABLE C-39a. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Forming South
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	126	119	126	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	6.48	6.14	5.73	6.12
Avg. stack temperature, °F	204.0	164.5	203.2	190.6
Isokinetic, %	107.9	98.7	104.5	103.7
Volume of gas sampled, dscf	41.416	77.103	48.655	55.725
Opacity average, %	12	11	10	--
Particulate matter				
Mass collected, gr	3.551	4.391	3.839	3.927
Concentration, gr/dscf	0.086	0.057	0.079	0.074
Emission level, lb/ton	3.56	2.66	3.89	3.37
Phenolic compounds				
Mass collected, gr	1.167	1.597	0.836	1.200
Concentration, gr/dscf	0.028	0.021	0.017	0.022
Emission level, lb/ton	1.17	0.97	0.85	1.00
Phenol				
Mass collected, gr	0.605	0.671	0.437	0.571
Concentration, gr/dscf	0.015	0.009	0.009	0.011
Emission level, lb/ton	0.61	0.41	0.44	0.49
Formaldehyde				
Mass collected, gr	0.393	0.676	0.525	0.531
Concentration, gr/dscf	0.010	0.009	0.011	0.010
Emission level, lb/ton	0.39	0.41	0.53	0.44

TABLE C-39b. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Forming South
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	126	119	126	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	6.48	6.14	5.73	6.12
Avg. stack temperture, °C	95.6	73.6	95.1	88.1
Isokinetic, %	107.9	98.7	104.5	103.7
Volume of gas sampled, Nm^3	1.173	2.183	1.378	1.578
Opacity average, %	12	11	10	--
Particulate matter				
Mass collected, mg	230.60	285.10	249.30	255.00
Concentration, mg/Nm^3	196.22	130.31	180.57	169.03
Emission level, kg/Mg	1.78	1.33	1.95	1.69
Phenolic compounds				
Mass collected, mg	75.80	103.70	54.30	77.93
Concentration, mg/Nm^3	64.50	47.40	39.33	50.41
Emission level, kg/Mg	0.59	0.49	0.43	0.50
Phenol				
Mass collected, mg	39.30	43.60	28.40	37.10
Concentration, mg/Nm^3	33.44	19.93	20.57	24.65
Emission level, kg/Mg	0.31	0.21	0.22	0.25
Formaldehyde				
Mass collected, mg	25.50	43.90	34.10	34.50
Concentration, mg/Nm^3	21.70	20.07	24.70	22.16
Emission level, kg/Mg	0.20	0.21	0.27	0.23

TABLE C-40a. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Curing/Cooling North
Product: R-11 Building Insulation
(English)

Run number:	1	2*	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	123	123	123	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	3.40	3.39	2.69	3.05
Avg. stack temperature, °F	208.1	163.0	172.3	190.2
Isokinetic, %	97.7	151.3	105.2	101.5
Volume of gas sampled, dscf	84.669	83.277	67.866	76.268
Opacity average, %	26	25	23	--
Particulate matter				
Mass collected, gr	4.512	3.262	1.957	3.235
Concentration, gr/dscf	0.053	0.039	0.029	0.041
Emission level, lb/ton	1.43	1.72	1.30	1.37
Phenolic compounds				
Mass collected, gr	0.052	0.066	0.045	0.049
Concentration, gr/dscf	0.001	0.001	0.001	0.001
Emission level, lb/ton	0.02	0.03	0.03	0.03
Phenol				
Mass collected, gr	0.011	0.010	0.015	0.013
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.01	0.01
Formaldehyde				
Mass collected, gr	1.192	1.072	1.203	1.198
Concentration, gr/dscf	0.014	0.013	0.018	0.016
Emission level, lb/ton	0.38	0.57	0.80	0.59

*Data excluded from average.

TABLE C-40b. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Curing/Cooling North
Product: R-11 Building Insulation
(Metric)

Run number:	1	2*	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	123	123	123	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	3.40	3.39	2.69	3.05
Avg. stack temperture, °C	97.8	72.8	78.0	87.90
Isokinetic, %	97.7	151.3	105.2	101.5
Volume of gas sampled, Nm³	2.397	2.358	1.922	2.160
Opacity average, %	26	25	23	--
Particulate matter				
Mass collected, mg	293.00	211.80	127.10	210.05
Concentration, mg/Nm³	121.95	89.63	66.00	93.98
Emission level, kg/Mg	0.72	0.86	0.65	0.69
Phenolic compounds				
Mass collected, mg	3.40	4.30	2.90	3.15
Concentration, mg/Nm³	1.42	1.82	1.51	1.47
Emission level, kg/Mg	0.01	0.02	0.02	0.02
Phenol				
Mass collected, mg	0.70	0.60	1.00	0.85
Concentration, mg/Nm³	0.29	0.25	0.52	0.41
Emission level, kg/Mg	0.00	0.00	0.01	0.01
Formaldehyde				
Mass collected, mg	77.40	69.60	78.10	77.75
Concentration, mg/Nm³	32.22	29.45	40.56	36.39
Emission level, kg/Mg	0.19	0.29	0.40	0.30

*Data excluded from average.

TABLE C-41a. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Curing South
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	3.01	3.03	3.39	3.14
Avg. stack temperature, °F	167.7	162.7	170.1	166.8
Isokinetic, %	91.1	98.3	98.2	95.9
Volume of gas sampled, dscf	101.481	110.458	104.919	105.619
Opacity average, %	27	30	26	--
Particulate matter				
Mass collected, gr	7.380	7.635	7.394	7.470
Concentration, gr/dscf	0.073	0.069	0.071	0.071
Emission level, lb/ton	3.35	3.17	3.05	3.19
Phenolic compounds				
Mass collected, gr	2.321	2.037	1.919	2.092
Concentration, gr/dscf	0.023	0.018	0.018	0.020
Emission level, lb/ton	1.05	0.85	0.79	0.90
Phenol				
Mass collected, gr	0.266	0.248	0.169	0.228
Concentration, gr/dscf	0.003	0.002	0.002	0.002
Emission level, lb/ton	0.12	0.10	0.07	0.10
Formaldehyde				
Mass collected, gr	1.980	2.994	1.962	2.312
Concentration, gr/dscf	0.020	0.027	0.019	0.022
Emission level, lb/ton	0.90	1.24	0.81	0.98

TABLE C-41b. SUMMARY OF TEST RESULTS--LINE F
Sampling Location: Curing South
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	07/09/81	07/10/81	07/10/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	98	99	100	--
Moisture, % by volume	3.01	3.03	3.39	3.14
Avg. stack temperture, °C	75.4	72.6	76.7	74.9
Isokinetic, %	91.1	98.3	98.2	95.9
Volume of gas sampled, Nm^3	2.874	3.128	2.971	2.991
Opacity average, %	27	30	26	--
Particulate matter				
Mass collected, mg	479.20	495.80	480.10	485.03
Concentration, mg/Nm^3	166.41	158.18	161.26	161.95
Emission level, kg/Mg	1.68	1.59	1.53	1.60
Phenolic compounds				
Mass collected, mg	150.70	132.30	124.60	135.87
Concentration, mg/Nm^3	52.33	42.21	41.85	45.46
Emission level, kg/Mg	0.53	0.43	0.40	0.45
Phenol				
Mass collected, mg	17.30	16.10	11.00	14.80
Concentration, mg/Nm^3	6.01	5.14	3.70	4.95
Emission level, kg/Mg	0.06	0.05	0.04	0.05
Formaldehyde				
Mass collected, mg	128.60	194.40	127.40	150.13
Concentration, mg/Nm^3	44.66	62.02	42.79	49.82
Emission level, kg/Mg	0.45	0.62	0.41	0.49

TABLE C-42a. SUMMARY OF TEST RESULTS--LINE G
Sampling Location: Forming
Product: Pipe Insulation
(English)

Run number:	1	2	3	Avg.
Date	05/28/81	05/28/81	05/29/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	113	114	104	--
Moisture, % by volume	4.09	4.61	4.39	4.36
Avg. stack temperature, °F	118	117.2	116.2	117.1
Isokinetic, %	94.2	98.4	101.0	97.9
Volume of gas sampled, dscf	73.110	77.294	71.274	73.893
Opacity average, %	18	20	27	--
Particulate matter				
Mass collected, gr	2.787	2.472	2.663	2.641
Concentration, gr/dscf	0.039	0.033	0.038	0.037
Emission level, lb/ton	15.20	12.75	14.69	14.21
Phenolic compounds				
Mass collected, gr	1.272	0.977	1.142	1.130
Concentration, gr/dscf	0.018	0.013	0.016	0.016
Emission level, lb/ton	6.94	5.04	6.30	6.09
Phenol				
Mass collected, gr	0.710	0.459	0.159	0.609
Concentration, gr/dscf	0.010	0.006	0.010	0.009
Emission level, lb/ton	3.87	2.37	3.63	3.29
Formaldehyde				
Mass collected, gr	0.104	0.150	0.119	0.124
Concentration, gr/dscf	0.002	0.002	0.002	0.002
Emission level, lb/ton	0.56	0.77	0.65	0.66

TABLE C-42b. SUMMARY OF TEST RESULTS--LINE G
Sampling Location: Forming
Product: Pipe Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	05/28/81	05/28/81	05/29/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	113	114	104	--
Moisture, % by volume	4.09	4.61	4.39	4.36
Avg. stack temperture, °C	47.8	47.4	46.8	47.3
Isokinetic, %	94.2	98.4	101.0	97.9
Volume of gas sampled, Nm^3	2.070	2.189	2.018	2.092
Opacity average, %	18	20	27	--
Particulate matter				
Mass collected, mg	185.80	164.80	177.50	176.03
Concentration, mg/Nm^3	89.56	75.14	87.76	84.15
Emission level, kg/Mg	7.60	6.38	7.34	7.11
Phenolic compounds				
Mass collected, mg	84.80	65.10	76.10	75.33
Concentration, mg/Nm^3	40.88	29.68	37.63	36.06
Emission level, kg/Mg	3.47	2.52	3.15	3.05
Phenol				
Mass collected, mg	47.30	30.60	43.90	40.60
Concentration, mg/Nm^3	22.80	13.95	21.71	19.49
Emission level, kg/Mg	1.93	1.18	1.82	1.65
Formaldehyde				
Mass collected, mg	6.90	10.00	7.90	8.27
Concentration, mg/Nm^3	3.33	4.56	3.91	3.93
Emission level, kg/Mg	0.28	0.39	0.33	0.33

TABLE C-43a. SUMMARY OF TEST RESULTS--LINE H
Sampling Location: Curing
Product: Pipe Insulation
(English)

Run number:	1	2	3	4	5	Avg.
Date	05/28/81	05/38/81	06/01/81	06/01/81	06/01/81	--
Sampling time, min	160	160	160	160	160	--
Glass pull rate, % of design	N/A	N/A	N/A	N/A	N/A	--
Moisture, % by volume	2.51	1.81	2.27	2.94	3.07	2.52
Avg. stack temperature, °F	234.1	237.5	251.5	250.4	250.1	244.7
Isokinetic, %	106.9	103.0	109.5	105.4	102.3	105.4
Volume of gas sampled, dscf	91.103	89.100	79.813	77.342	25.103	82.492
Opacity average, %	4	3	1	1	2	--
Particulate matter						
Mass collected, gr	3.405	2.940	3.254	3.285	3.447	3.266
Concentration, gr/dscf	0.038	0.034	0.042	0.044	0.047	0.041
Emission level, lb/ton	11.61	10.41	10.84	11.36	12.29	11.30
Phenolic compounds						
Mass collected, gr	1.568	1.163	1.256	1.428	1.647	1.412
Concentration, gr/dscf	0.018	0.013	0.016	0.019	0.023	0.018
Emission level, lb/ton	5.35	4.12	4.18	4.94	5.87	4.89
Phenol						
Mass collected, gr	0.150	0.095	0.123	0.083	0.110	0.112
Concentration, gr/dscf	0.002	0.001	0.002	0.001	0.002	0.002
Emission level, lb/ton	0.51	0.33	0.41	0.29	0.39	0.39
Formaldehyde						
Mass collected, gr	0.330	0.138	0.191	0.210	0.096	0.193
Concentration, gr/dscf	0.004	0.002	0.003	0.003	0.001	0.003
Emission level, lb/ton	1.13	0.49	0.63	0.73	0.34	0.66

N/A = Not applicable.

TABLE C-43b. SUMMARY OF TEST RESULTS--LINE H
Sampling Location: Curing
Product: Pipe Insulation
(Metric)

Run number:	1	2	3	4	5	Avg.
Date	05/28/81	05/28/81	06/01/81	06/01/81	06/01/81	--
Sampling time, min	160	160	160	160	160	--
Glass pull rate, % of design	N/A	N/A	N/A	N/A	N/A	--
Moisture, % by volume	2.51	1.81	2.27	2.94	3.07	2.52
Avg. stack temperture, °C	112.3	114.2	122.0	121.3	121.2	118.2
Isokinetic, %	106.9	103.0	109.5	105.4	102.3	105.4
Volume of gas sampled, Nm^3	2.580	2.523	2.260	2.190	2.127	2.336
Opacity average, %	4	3	1	1	2	--
Particulate matter						
Mass collected, mg	227.00	196.00	216.90	219.00	229.80	217.74
Concentration, mg/Nm^3	87.81	77.52	95.77	99.79	107.29	93.74
Emission level, kg/Mg	5.81	5.20	5.42	5.68	6.15	5.65
Phenolic compounds						
Mass collected, mg	104.50	77.50	83.70	95.20	109.80	94.14
Concentration, mg/Nm^3	40.42	30.65	36.96	43.38	51.52	40.59
Emission level, kg/Mg	2.67	2.06	2.09	2.47	2.94	2.45
Phenol						
Mass collected, mg	10.00	6.30	8.20	5.50	7.30	7.46
Concentration, mg/Nm^3	3.87	2.49	3.62	2.51	3.43	3.18
Emission level, kg/Mg	0.26	0.17	0.21	0.14	0.20	0.19
Formaldehyde						
Mass collected, mg	22.00	9.20	12.70	14.00	6.40	12.86
Concentration, mg/Nm^3	8.51	3.64	5.61	6.38	3.00	5.43
Emission level, kg/Mg	0.56	0.24	0.32	0.36	0.17	0.33

N/A = Not applicable.

TABLE C-44a. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: Forming East
Product: Ductboard
(English)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	6.71	7.95	7.85	7.50
Avg. stack temperature, °F	152.6	147.0	150.7	150.1
Isokinetic, %	103.4	108.1	102.7	104.7
Volume of gas sampled, dscf	56.025	59.242	49.235	54.834
Opacity average, %	26	14	24	--
Particulate matter				
Mass collected, gr	3.668	3.905	2.462	3.345
Concentration, gr/dscf	0.066	0.066	0.050	0.061
Emission level, lb/ton	43.48	51.24	30.72	41.81
Phenolic compounds				
Mass collected, gr	1.109	1.361	0.759	1.076
Concentration, gr/dscf	0.020	0.023	0.015	0.019
Emission level, lb/ton	13.14	17.86	9.47	13.49
Phenol				
Mass collected, gr	0.436	0.504	0.306	0.415
Concentration, gr/dscf	0.008	0.009	0.006	0.008
Emission level, lb/ton	5.17	6.61	3.82	5.20
Formaldehyde				
Mass collected, gr	0.836	0.930	0.610	0.792
Concentration, gr/dscf	0.015	0.016	0.012	0.014
Emission level, lb/ton	9.91	12.20	7.61	9.91

TABLE C-44b. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: Forming East
Product: Ductboard
(Metric)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	6.71	7.95	7.85	7.50
Avg. stack temperture, °C	67.0	63.9	66.0	65.6
Isokinetic, %	103.4	108.1	102.7	104.7
Volume of gas sampled, Nm^3	1.586	1.678	1.394	1.553
Opacity average, %	26	14	24	--
Particulate matter				
Mass collected, mg	238.20	253.60	159.90	217.23
Concentration, mg/Nm^3	149.83	150.86	114.45	138.38
Emission level, kg/Mg	21.74	25.62	15.36	20.91
Phenolic compounds				
Mass collected, mg	72.00	88.40	49.30	69.90
Concentration, mg/Nm^3	45.29	52.59	35.29	44.39
Emission level, kg/Mg	6.57	8.93	4.74	6.75
Phenol				
Mass collected, mg	28.30	32.70	19.90	26.97
Concentration, mg/Nm^3	17.80	19.45	14.24	17.16
Emission level, kg/Mg	2.59	3.31	1.91	2.60
Formaldehyde				
Mass collected, mg	54.30	60.40	39.60	51.43
Concentration, mg/Nm^3	34.16	35.93	28.34	32.81
Emission level, kg/Mg	4.96	6.10	3.81	4.96

TABLE C-45a. SUMMARY OF TEST RESULTS--LINE I

Sampling Location: Forming West
Product: Ductboard
(English)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	6.64	6.69	7.35	6.89
Avg. stack temperature, °F	147.2	140.5	152.7	146.8
Isokinetic, %	97.4	92.3	103.2	97.6
Volume of gas sampled, dscf	56.251	62.576	58.277	59.035
Opacity average, %	25	12	23	--
Particulate matter				
Mass collected, gr	3.507	3.728	3.544	3.593
Concentration, gr/dscf	0.062	0.060	0.061	0.061
Emission level, lb/ton	44.49	51.85	44.35	46.90
Phenolic compounds				
Mass collected, gr	0.796	0.742	0.910	0.816
Concentration, gr/dscf	0.014	0.012	0.016	0.014
Emission level, lb/ton	10.10	10.32	11.39	10.60
Phenol				
Mass collected, gr	0.300	0.345	0.339	0.328
Concentration, gr/dscf	0.005	0.006	0.006	0.006
Emission level, lb/ton	3.81	4.80	4.24	4.28
Formaldehyde				
Mass collected, gr	0.608	0.955	0.596	0.720
Concentration, gr/dscf	0.011	0.015	0.010	0.012
Emission level, lb/ton	7.72	13.28	7.46	9.49

TABLE C-45b. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: Forming West
Product: Ductboard
(Metric)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	6.64	6.69	7.35	6.89
Avg. stack temperture, °C	64.0	60.3	67.1	63.8
Isokinetic, %	97.4	92.3	103.2	97.6
Volume of gas sampled, Nm^3	1.593	1.772	1.650	1.672
Opacity average, %	25	12	23	--
Particulate matter				
Mass collected, mg	227.70	242.10	230.1	233.30
Concentration, mg/Nm^3	142.65	136.34	139.14	139.38
Emission level, kg/Mg	22.25	25.93	22.18	23.45
Phenolic compounds				
Mass collected, mg	51.70	48.20	59.10	53.00
Concentration, mg/Nm^3	32.39	27.14	35.74	31.76
Emission level, kg/Mg	5.05	5.16	5.70	5.30
Phenol				
Mass collected, mg	19.50	22.40	22.00	21.30
Concentration, mg/Nm^3	12.22	12.62	13.30	12.71
Emission level, kg/Mg	1.91	2.40	2.12	2.14
Formaldehyde				
Mass collected, mg	39.50	62.00	38.70	46.73
Concentration, mg/Nm^3	24.75	34.92	23.40	27.69
Emission level, kg/Mg	3.86	6.64	3.73	4.74

TABLE C-46a. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: Cooling
Product: Ductboard
(English)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	2.99	2.96	3.30	3.08
Avg. stack temperature, °F	246.3	258.7	256.3	253.8
Isokinetic, %	108.3	104.3	99.4	104.0
Volume of gas sampled, dscf	79.373	64.890	67.610	70.624
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	1.106	1.060	0.972	1.046
Concentration, gr/dscf	0.014	0.016	0.014	0.015
Emission level, lb/ton	0.62	0.64	0.62	0.63
Phenolic compounds				
Mass collected, gr	0.009	0.009	0.009	0.009
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.01	0.01	0.01	0.01
Phenol				
Mass collected, gr	0.008	0.008	0.011	0.009
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.00	0.00	0.01	0.00
Formaldehyde				
Mass collected, gr	0.114	0.148	0.131	0.131
Concentration, gr/dscf	0.001	0.002	0.002	0.002
Emission level, lb/ton	0.06	0.09	0.08	0.08

N/A = Not applicable.

TABLE C-46b. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: Cooling
Product: Ductboard
(Metric)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	2.99	2.96	3.30	3.08
Avg. stack temperture, °C	119.1	126.0	124.6	123.2
Isokinetic, %	108.3	104.3	99.4	104.0
Volume of gas sampled, Nm^3	2.248	1.837	1.914	2.000
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	71.80	68.70	63.10	67.87
Concentration, mg/Nm^3	31.88	37.31	32.89	34.03
Emission level, kg/Mg	0.31	0.32	0.31	0.31
Phenolic compounds				
Mass collected, mg	0.60	0.60	0.60	0.60
Concentration, mg/Nm^3	0.27	0.33	0.31	0.30
Emission level, kg/Mg	0.01	0.01	0.01	0.01
Phenol				
Mass collected, mg	0.50	0.50	0.70	0.57
Concentration, mg/Nm^3	0.22	0.27	0.37	0.29
Emission level, kg/Mg	0.00	0.00	0.00	0.00
Formaldehyde				
Mass collected, mg	7.40	9.60	8.50	8.50
Concentration, mg/Nm^3	3.29	5.21	4.43	4.31
Emission level, kg/Mg	0.03	0.05	0.04	0.04

N/A = Not applicable.

TABLE C-47a. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: HVAF Bypass
Product: Ductboard
(English)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	2.74	2.75	2.94	2.81
Avg. stack temperature, °F	166.1	168.1	166.7	167.0
Isokinetic, %	97.8	96.4	94.3	96.2
Volume of gas sampled, dscf	95.253	93.608	91.775	93.545
Opacity average, %	22	17	21	--
Particulate matter				
Mass collected, gr	2.678	5.182	2.057	3.306
Concentration, gr/dscf	0.028	0.055	0.022	0.035
Emission level, lb/ton	4.60	9.39	3.84	5.94
Phenolic compounds				
Mass collected, gr	0.413	0.300	0.263	0.325
Concentration, gr/dscf	0.004	0.003	0.003	0.003
Emission level, lb/ton	0.71	0.54	0.49	0.58
Phenol				
Mass collected, gr	0.037	0.055	0.042	0.045
Concentration, gr/dscf	0.000	0.001	0.001	0.001
Emission level, lb/ton	0.06	0.10	0.08	0.08
Formaldehyde				
Mass collected, gr	0.231	0.462	0.259	0.317
Concentration, gr/dscf	0.002	0.005	0.003	0.003
Emission level, lb/ton	0.40	0.84	0.48	0.57

TABLE C-47b. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: HVAF Bypass
Product: Ductboard
(Metric)

Run number:	1	2	3	Avg.
Date	07/07/81	07/07/81	07/08/81	--
Sampling time, min	120	120	120	--
Glass pull rate, % of design	99	95	94	--
Moisture, % by volume	2.74	2.75	2.94	2.81
Avg. stack temperture, °C	74.5	75.6	74.8	75.0
Isokinetic, %	97.8	96.4	94.3	96.2
Volume of gas sampled, Nm^3	2.697	2.651	2.599	2.649
Opacity average, %	22	17	21	--
Particulate matter				
Mass collected, mg	173.90	336.50	133.60	214.67
Concentration, mg/Nm^3	64.34	126.68	51.30	80.77
Emission level, kg/Mg	2.30	4.65	1.92	2.96
Phenolic compounds				
Mass collected, mg	26.80	19.50	17.10	21.13
Concentration, mg/Nm^3	9.92	7.34	6.57	7.94
Emission level, kg/Mg	0.36	0.27	0.25	0.29
Phenol				
Mass collected, mg	2.40	3.60	2.70	2.90
Concentration, mg/Nm^3	0.89	1.36	1.04	1.10
Emission level, kg/Mg	0.03	0.05	0.04	0.04
Formaldehyde				
Mass collected, mg	15.00	30.00	16.80	20.60
Concentration, mg/Nm^3	5.55	11.29	6.45	7.76
Emission level, kg/Mg	0.20	0.42	0.24	0.29

TABLE C-48a. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: HVAF Outlet Without Water Sprays
Product: Ductboard
(English)

Run number:	1	2	3	Avg.
Date	07/11/81	07/11/81	07/11/81	--
Sampling time, min	125	125	125	--
Glass pull rate, % of design	99	99	99	--
Moisture, % by volume	3.34	3.24	3.39	3.32
Avg. stack temperature, °F	154.4	158.1	157.7	156.7
Isokinetic, %	101.6	99.1	99.0	99.9
Volume of gas sampled, dscf	55.691	53.592	54.847	54.710
Opacity average, %	0	0	0	--
Particulate matter				
Mass collected, gr	0.341	0.233	0.299	0.291
Concentration, gr/dscf	0.006	0.004	0.006	0.005
Emission level, lb/ton	1.36	0.95	1.23	1.18
Phenolic compounds				
Mass collected, gr	0.134	0.129	0.074	0.112
Concentration, gr/dscf	0.002	0.002	0.001	0.002
Emission level, lb/ton	0.54	0.53	0.30	0.46
Phenol				
Mass collected, gr	0.012	0.020	0.020	0.017
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.05	0.08	0.08	0.07
Formaldehyde				
Mass collected, gr	0.303	0.126	0.120	0.183
Concentration, gr/dscf	0.006	0.002	0.002	0.003
Emission level, lb/ton	1.21	0.52	0.49	0.74

TABLE C-48b. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: HVAF Outlet Without Water Sprays
Product: Ductboard
(Metric)

Run number:	1	2	3	Avg.
Date	07/11/81	07/11/81	07/11/81	--
Sampling time, min	125	125	125	--
Glass pull rate, % of design	99	99	99	--
Moisture, % by volume	3.34	3.24	3.39	3.32
Avg. stack temperture, °C	68.0	70.0	69.8	69.3
Isokinetic, %	101.6	99.1	99.0	99.9
Volume of gas sampled, Nm^3	1.577	1.517	1.553	1.549
Opacity average, %	0	0	0	--
Particulate matter				
Mass collected, mg	22.10	15.10	19.40	18.87
Concentration, mg/Nm^3	13.99	9.93	12.47	12.13
Emission level, kg/Mg	0.68	0.48	0.62	0.59
Phenolic compounds				
Mass collected, mg	8.70	8.40	4.80	7.30
Concentration, mg/Nm^3	5.51	5.52	3.08	4.70
Emission level, kg/Mg	0.27	0.27	0.15	0.23
Phenol				
Mass collected, mg	0.80	1.30	1.30	1.13
Concentration, mg/Nm^3	0.51	0.86	0.84	0.74
Emission level, kg/Mg	0.03	0.04	0.04	0.04
Formaldehyde				
Mass collected, mg	19.70	8.20	7.80	11.90
Concentration, mg/Nm^3	12.47	5.39	5.01	7.62
Emission level, kg/Mg	0.61	0.26	0.25	0.37

TABLE C-49a. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: HVAF Outlet With Water Sprays
Product: Ductboard
(English)

Run number:	2*	3*	4*	Avg.
Date	07/15/81	07/15/81	07/15/81	--
Sampling time, min	125	125	125	--
Glass pull rate, % of design	96	96	96	--
Moisture, % by volume	5.01	4.78	4.83	--
Avg. stack temperature, °F	103.2	103.4	100.1	--
Isokinetic, %	96.4	96.8	98.2	--
Volume of gas sampled, dscf	62.566	61.461	62.264	--
Opacity average, %	0	2	3	--
Particulate matter				
Mass collected, gr	1.115	0.847	1.542	--
Concentration, gr/dscf	0.018	0.014	0.025	--
Emission level, lb/ton	5.29	4.00	7.19	--
Phenolic compounds				
Mass collected, gr	0.111	0.112	0.154	--
Concentration, gr/dscf	0.002	0.002	0.003	--
Emission level, lb/ton	0.53	0.53	0.72	--
Phenol				
Mass collected, gr	0.040	0.020	0.025	--
Concentration, gr/dscf	0.001	0.000	0.000	--
Emission level, lb/ton	0.19	0.09	0.11	--
Formaldehyde				
Mass collected, gr	0.128	0.139	0.188	--
Concentration, gr/dscf	0.002	0.002	0.003	--
Emission level, lb/ton	0.61	0.66	0.88	--

*Data excluded.

TABLE C-49b. SUMMARY OF TEST RESULTS--LINE I
Sampling Location: HVAF Outlet With Water Sprays
Product: Ductboard
(Metric)

Run number:	2*	3*	4*	Avg.
Date	07/15/81	07/15/81	07/15/81	--
Sampling time, min	125	125	125	--
Glass pull rate, % of design	96	96	96	--
Moisture, % by volume	5.01	4.78	4.83	--
Avg. stack temperture, °C	39.5	39.7	37.8	--
Isokinetic, %	96.4	96.8	98.2	--
Volume of gas sampled, Nm^3	1.772	1.740	1.763	--
Opacity average, %	0	2	3	--
Particulate matter				
Mass collected, mg	72.40	55.00	100.10	--
Concentration, mg/Nm^3	40.78	31.54	56.66	--
Emission level, kg/Mg	2.65	2.00	3.60	--
Phenolic compounds				
Mass collected, mg	7.20	7.30	10.00	--
Concentration, mg/Nm^3	4.06	4.19	5.66	--
Emission level, kg/Mg	0.27	0.27	0.36	--
Phenol				
Mass collected, mg	2.60	1.30	1.60	--
Concentration, mg/Nm^3	1.46	0.75	0.91	--
Emission level, kg/Mg	0.10	0.05	0.06	--
Formaldehyde				
Mass collected, mg	8.30	9.00	12.20	--
Concentration, mg/Nm^3	4.68	5.16	6.91	--
Emission level, kg/Mg	0.31	0.33	0.44	--

*Data excluded.

TABLE C-50a. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Forming East
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	120	120	120	120	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	8.11	7.86	8.51	9.28	8.44
Avg. stack temperature, °F	155.4	151.8	146.5	149.6	150.8
Isokinetic, %	97.5	95.3	98.4	99.9	97.8
Volume of gas sampled, dscf	73.700	71.363	73.131	69.969	72.041
Opacity average, %	0	0	0	0	--
Particulate matter					
Mass collected, gr	1.722	1.851	2.321	1.848	1.936
Concentration, gr/dscf	0.023	0.026	0.032	0.026	0.027
Emission level, lb/ton	26.54	29.19	34.91	27.39	29.51
Phenolic compounds					
Mass collected, gr	0.214	0.203	0.182	0.248	0.212
Concentration, gr/dscf	0.003	0.003	0.003	0.004	0.003
Emission level, lb/ton	3.30	3.21	2.73	3.67	3.23
Phenol					
Mass collected, gr	0.109	0.072	0.088	0.074	0.086
Concentration, gr/dscf	0.002	0.001	0.001	0.001	0.001
Emission level, lb/ton	1.69	1.14	1.32	1.09	1.31
Formaldehyde					
Mass collected, gr	0.314	0.282	0.313	0.243	0.288
Concentration, gr/dscf	0.004	0.004	0.004	0.004	0.004
Emission level, lb/ton	4.84	4.44	4.70	3.61	4.40

TABLE C-50b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Forming East
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	120	120	120	120	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	8.11	7.86	8.51	9.28	8.44
Avg. stack temperture, °C	68.6	66.6	63.6	65.3	66.0
Isokinetic, %	97.5	95.3	98.4	99.9	97.8
Volume of gas sampled, Nm^3	2.087	2.021	2.071	1.981	2.04
Opacity average, %	0	0	0	0	--
Particulate matter					
Mass collected, mg	111.80	120.20	150.70	120.00	125.68
Concentration, mg/Nm^3	53.46	59.36	72.62	60.44	61.47
Emission level, kg/Mg	13.27	14.60	17.46	13.70	14.76
Phenolic compounds					
Mass collected, mg	13.90	13.20	11.80	16.10	13.75
Concentration, mg/Nm^3	6.65	6.52	5.69	8.11	6.74
Emission level, kg/Mg	1.65	1.61	1.37	1.84	1.62
Phenol					
Mass collected, mg	7.10	4.70	5.70	4.80	5.58
Concentration, mg/Nm^3	3.40	2.32	2.75	2.42	2.72
Emission level, kg/Mg	0.85	0.57	0.66	0.54	0.66
Formaldehyde					
Mass collected, mg	20.40	18.30	20.30	15.80	18.70
Concentration, mg/Nm^3	9.75	9.04	9.78	7.96	9.13
Emission level, kg/Mg	2.42	2.22	2.35	1.81	2.20

TABLE C-51a. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Forming West
Product: R-11 Building Insulation
(English)

Run number:	1*	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	120	120	120	120	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	8.74	8.60	8.84	7.59	8.34
Avg. stack temperature, °F	155.2	153.3	150.3	155.6	153.1
Isokinetic, %	85.7	97.8	99.4	99.3	98.8
Volume of gas sampled, dscf	58.395	75.562	73.147	77.503	75.404
Opacity average, %	0	0	0	0	--
Particulate matter					
Mass collected, gr	2.087	0.668	1.645	1.514	1.276
Concentration, gr/dscf	0.036	0.009	0.023	0.020	0.017
Emission level, lb/ton	36.86	10.35	24.68	22.74	19.26
Phenolic compounds					
Mass collected, gr	0.216	0.254	0.229	0.193	0.225
Concentration, gr/dscf	0.004	0.003	0.003	0.003	0.003
Emission level, lb/ton	3.81	3.94	3.44	2.89	3.42
Phenol					
Mass collected, gr	0.069	0.105	0.097	0.058	0.087
Concentration, gr/dscf	0.001	0.001	0.001	0.001	0.001
Emission level, lb/ton	1.22	1.62	1.46	0.88	1.32
Formaldehyde					
Mass collected, gr	0.279	0.317	0.347	0.216	0.293
Concentration, gr/dscf	0.005	0.004	0.005	0.003	0.004
Emission level, lb/ton	4.92	4.91	5.20	3.24	4.45

*Data excluded from average.

TABLE C-51b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Forming West
Product: R-11 Building Insulation
(Metric)

Run number:	1*	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	120	120	120	120	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	8.74	8.60	8.84	7.59	8.34
Avg. stack temperture, °C	68.4	67.4	65.7	68.7	67.3
Isokinetic, %	85.7	97.8	99.4	99.3	98.8
Volume of gas sampled, Nm^3	1.654	2.140	2.071	2.195	2.135
Opacity average, %	0	0	0	0	--
Particulate matter					
Mass collected, mg	135.50	43.40	106.80	98.30	82.83
Concentration, mg/Nm^3	81.77	20.24	51.45	44.70	38.80
Emission level, kg/Mg	18.43	5.18	12.34	11.37	9.63
Phenolic compounds					
Mass collected, mg	14.00	16.50	14.90	12.50	14.63
Concentration, mg/Nm^3	8.45	7.70	7.18	5.68	6.85
Emission level, kg/Mg	1.91	1.97	1.72	1.45	1.71
Phenol					
Mass collected, mg	4.50	6.80	6.30	3.80	5.63
Concentration, mg/Nm^3	2.72	3.17	3.04	1.73	2.65
Emission level, kg/Mg	0.61	0.81	0.73	0.44	0.66
Formaldehyde					
Mass collected, mg	18.10	20.60	22.50	14.00	19.03
Concentration, mg/Nm^3	10.92	9.61	10.84	6.37	8.94
Emission level, kg/Mg	2.46	2.46	2.60	1.62	2.23

*Data excluded from average.

TABLE C-52a. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing East Without Water Sprays
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	126	126	126	126	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	3.51	3.41	4.24	3.30	3.62
Avg. stack temperature, °F	252.7	250.3	249.9	254.7	251.9
Isokinetic, %	95.3	97.7	100.7	96.3	97.5
Volume of gas sampled, dscf	68.298	70.101	74.610	67.868	70.219
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	1.047	1.272	1.110	1.275	1.176
Concentration, gr/dscf	0.015	0.018	0.015	0.019	0.017
Emission level, lb/ton	1.91	2.26	1.89	2.27	2.08
Phenolic compounds					
Mass collected, gr	0.154	0.160	0.139	0.123	0.144
Concentration, gr/dscf	0.002	0.002	0.002	0.002	0.002
Emission level, lb/ton	0.28	0.29	0.24	0.22	0.258
Phenol					
Mass collected, gr	0.018	0.009	0.009	0.014	0.013
Concentration, gr/dscf	0.000	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.03	0.02	0.02	0.02	0.02
Formaldehyde					
Mass collected, gr	0.342	0.528	0.257	0.114	0.310
Concentration, gr/dscf	0.005	0.008	0.004	0.002	0.005
Emission level, lb/ton	0.62	0.94	0.44	0.20	0.55

N/A = Not applicable.

TABLE C-52b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing East Without Water Sprays
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	126	126	126	126	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	3.51	3.41	4.24	3.30	3.62
Avg. stack temperture, °C	122.6	121.3	121.0	123.7	122.2
Isokinetic, %	95.3	97.7	100.7	96.3	97.5
Volume of gas sampled, Nm^3	1.934	1.985	2.113	1.922	1.989
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	68.00	82.60	72.10	82.80	76.38
Concentration, mg/Nm^3	35.09	41.52	34.06	42.99	38.42
Emission level, kg/Mg	0.96	1.13	0.95	1.14	1.05
Phenolic compounds					
Mass collected, mg	10.00	10.40	9.00	8.00	9.35
Concentration, mg/Nm^3	5.16	5.23	4.25	4.15	4.70
Emission level, kg/Mg	0.14	0.15	0.12	0.11	0.13
Phenol					
Mass collected, mg	1.20	0.60	0.60	0.90	0.83
Concentration, mg/Nm^3	0.62	0.30	0.28	0.47	0.42
Emission level, kg/Mg	0.02	0.01	0.01	0.01	0.01
Formaldehyde					
Mass collected, mg	22.20	34.30	16.70	7.40	20.15
Concentration, mg/Nm^3	11.46	17.24	7.89	3.84	10.11
Emission level, kg/Mg	0.31	0.47	0.22	0.10	0.28

N/A = Not applicable.

TABLE C-53a. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing West Without Water Sprays
Product: R-11 Building Insulation
(English)

Run number:	1	2*	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	126	126	126	126	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	3.57	3.60	3.76	3.71	3.68
Avg. stack temperature, °F	275.9	278.5	268.4	269.5	271.3
Isokinetic, %	100.6	100.0	101.4	100.1	100.7
Volume of gas sampled, dscf	71.380	71.965	72.734	72.780	72.298
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, gr	1.737	3.091	2.233	2.587	2.186
Concentration, gr/dscf	0.024	0.043	0.031	0.036	0.030
Emission level, lb/ton	2.05	3.68	2.58	3.03	2.55
Phenolic compounds					
Mass collected, gr	0.074	0.080	0.125	0.079	0.093
Concentration, gr/dscf	0.001	0.001	0.002	0.001	0.001
Emission level, lb/ton	0.09	0.10	0.14	0.09	0.107
Phenol					
Mass collected, gr	0.012	0.082	0.062	0.009	0.028
Concentration, gr/dscf	0.000	0.001	0.001	0.000	0.000
Emission level, lb/ton	0.01	0.10	0.07	0.01	0.03
Formaldehyde					
Mass collected, gr	0.337	0.328	0.400	0.231	0.323
Concentration, gr/dscf	0.005	0.005	0.006	0.003	0.005
Emission level, lb/ton	0.40	0.39	0.46	0.27	0.38

*Data excluded from average.
N/A = Not applicable.

TABLE C-53b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing West Without Water Sprays
Product: R-11 Building Insulation
(Metric)

Run number:	1	2*	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	126	126	126	126	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	3.57	3.60	3.76	3.71	3.68
Avg. stack temperture, °C	135.5	136.9	131.3	132.0	132.9
Isokinetic, %	100.6	100.0	101.4	100.1	100.7
Volume of gas sampled, Nm^3	2.021	2.038	2.060	2.063	2.048
Opacity average, %	N/A	N/A	N/A	N/A	--
Particulate matter					
Mass collected, mg	112.80	200.70	145.00	168.00	141.93
Concentration, mg/Nm^3	55.69	98.28	70.25	81.25	69.06
Emission level, kg/Mg	1.03	1.84	1.29	1.52	1.28
Phenolic compounds					
Mass collected, mg	4.80	5.20	8.10	5.10	6.00
Concentration, mg/Nm^3	2.37	2.55	3.93	2.47	2.9
Emission level, kg/Mg	0.05	0.05	0.07	0.05	0.06
Phenol					
Mass collected, mg	0.80	5.30	4.00	0.06	1.80
Concentration, mg/Nm^3	0.40	2.60	1.94	0.29	0.88
Emission level, kg/Mg	0.01	0.05	0.04	0.01	0.02
Formaldehyde					
Mass collected, mg	21.90	21.30	26.00	15.00	20.97
Concentration, mg/Nm^3	10.81	10.43	12.60	7.25	10.2
Emission level, kg/Mg	0.20	0.20	0.23	0.14	0.19

*Data excluded from average.
N/A = Not applicable.

TABLE C-54a. SUMMARY OF TEST RESULTS--LINE J

Sampling Location: HVAF Outlet Without Water Sprays
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	126	126	126	126	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	3.15	3.02	3.33	3.32	3.21
Avg. stack temperature, °F	204.5	214.2	183.8	207.0	202.4
Isokinetic, %	100.6	101.3	101.3	103.8	101.8
Volume of gas sampled, dscf	61.179	61.237	63.483	62.524	62.106
Opacity average, %	3	2	2	2	--
Particulate matter					
Mass collected, gr	0.245	0.266	0.542	0.460	0.378
Concentration, gr/dscf	0.004	0.004	0.009	0.007	0.006
Emission level, lb/ton	1.64	1.77	3.54	2.94	2.47
Phenolic compounds					
Mass collected, gr	0.074	0.063	0.063	0.065	0.066
Concentration, gr/dscf	0.001	0.001	0.001	0.001	0.001
Emission level, lb/ton	0.49	0.42	0.41	0.41	0.43
Phenol					
Mass collected, gr	0.029	0.018	0.039	0.006	0.023
Concentration, gr/dscf	0.001	0.000	0.001	0.000	0.000
Emission level, lb/ton	0.20	0.12	0.25	0.04	0.15
Formaldehyde					
Mass collected, gr	0.169	0.172	0.139	0.109	0.147
Concentration, gr/dscf	0.003	0.003	0.002	0.002	0.003
Emission level, lb/ton	1.13	1.14	0.91	0.70	0.97

TABLE C-54b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: HVAF Outlet Without Water Sprays
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	4	Avg.
Date	07/13/81	07/13/81	07/14/81	07/14/81	--
Sampling time, min	126	126	126	126	--
Glass pull rate, % of design	93	93	95	95	--
Moisture, % by volume	3.15	3.02	3.33	3.32	3.21
Avg. stack temperture, °C	95.8	101.2	84.3	97.2	94.6
Isokinetic, %	100.6	101.3	101.3	103.8	101.8
Volume of gas sampled, Nm^3	1.732	1.734	1.798	1.770	1.759
Opacity average, %	2	2	2	2	--
Particulate matter					
Mass collected, mg	15.90	17.30	35.20	29.90	24.58
Concentration, mg/Nm^3	9.16	9.96	19.54	16.85	13.88
Emission level, kg/Mg	0.82	0.89	1.77	1.47	1.24
Phenolic compounds					
Mass collected, mg	4.80	4.10	4.10	4.20	4.30
Concentration, mg/Nm^3	2.77	2.36	2.28	2.37	2.45
Emission level, kg/Mg	0.25	0.21	0.21	0.21	0.22
Phenol					
Mass collected, mg	1.90	1.20	2.50	0.40	1.50
Concentration, mg/Nm^3	1.09	0.69	1.39	0.23	0.85
Emission level, kg/Mg	0.10	0.06	0.13	0.02	0.08
Formaldehyde					
Mass collected, mg	11.00	11.20	9.00	7.10	9.58
Concentration, mg/Nm^3	6.34	6.45	5.00	4.00	5.45
Emission level, kg/Mg	0.57	0.57	0.46	0.35	0.49

TABLE C-55a. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: HVAF Outlet With Water Sprays
Product: R-11 Building Insulation
(English)

Run number:	1*	2*	3*	Avg.
Date	07/15/81	07/15/81	07/16/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	91	91	91	--
Moisture, % by volume	5.25	4.62	5.06	--
Avg. stack temperature, °F	148.2	137.5	142.6	--
Isokinetic, %	101.6	101.6	100.5	--
Volume of gas sampled, dscf	59.328	64.468	61.870	--
Opacity average, %	2	6	2	--
Particulate matter				
Mass collected, gr	2.121	0.485	0.608	--
Concentration, gr/dscf	0.036	0.008	0.010	--
Emission level, lb/ton	14.44	3.31	4.19	--
Phenolic compounds				
Mass collected, gr	0.059	0.049	0.079	--
Concentration, gr/dscf	0.001	0.001	0.001	--
Emission level, lb/ton	0.40	0.34	0.54	--
Phenol				
Mass collected, gr	0.017	0.008	0.009	--
Concentration, gr/dscf	0.000	0.000	0.000	--
Emission level, lb/ton	0.12	0.05	0.06	--
Formaldehyde				
Mass collected, gr	0.131	0.126	0.099	--
Concentration, gr/dscf	0.002	0.002	0.002	--
Emission level, lb/ton	0.87	0.86	0.68	--

*Data excluded.

TABLE C-55b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: HVAF Outlet With Water Sprays
Product: R-11 Building Insulation
(Metric)

Run number:	1*	2*	3*	Avg.
Date	07/15/81	07/15/81	07/16/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	91	91	91	--
Moisture, % by volume	5.25	4.62	5.06	--
Avg. stack temperture, °C	64.6	58.6	61.5	--
Isokinetic, %	101.6	101.6	100.5	--
Volume of gas sampled, Nm^3	1.680	1.825	1.752	--
Opacity average, %	2	6	2	--
Particulate matter				
Mass collected, mg	137.70	31.50	39.50	--
Concentration, mg/Nm^3	81.79	17.22	22.50	--
Emission level, kg/Mg	7.22	1.66	2.10	--
Phenolic compounds				
Mass collected, mg	3.80	3.20	5.10	--
Concentration, mg/Nm^3	2.26	1.75	2.91	--
Emission level, kg/Mg	0.20	0.17	0.27	--
Phenol				
Mass collected, mg	1.10	0.50	0.60	--
Concentration, mg/Nm^3	0.65	0.27	0.34	--
Emission level, kg/Mg	0.06	0.03	0.03	--
Formaldehyde				
Mass collected, mg	8.50	8.20	6.40	--
Concentration, mg/Nm^3	5.05	4.48	3.65	--
Emission level, kg/Mg	0.44	0.43	0.34	--

*Data excluded from average.

TABLE C-56a. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing East With Water Sprays
Product: R-11 Building Insulation
(English)

Run number:	1*	2	3	Avg.
Date	07/15/81	07/15/81	07/16/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	91	91	91	--
Moisture, % by volume	4.09	4.02	4.14	4.08
Avg. stack temperature, °F	256.4	255.6	253.8	254.7
Isokinetic, %	111.9	103.8	98.1	101.0
Volume of gas sampled, dscf	72.192	73.074	68.429	70.752
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	1.092	1.264	0.793	1.029
Concentration, gr/dscf	0.015	0.017	0.012	0.015
Emission level, lb/ton	1.74	2.18	1.45	1.82
Phenolic compounds				
Mass collected, gr	0.166	0.151	0.152	0.152
Concentration, gr/dscf	0.002	0.002	0.002	0.002
Emission level, lb/ton	0.27	0.26	0.28	0.27
Phenol				
Mass collected, gr	0.028	0.009	0.020	0.015
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.04	0.02	0.04	0.03
Formaldehyde				
Mass collected, gr	0.143	0.263	0.142	0.203
Concentration, gr/dscf	0.002	0.004	0.002	0.003
Emission level, lb/ton	0.23	0.45	0.26	0.36

*Data excluded from average.
N/A = Not applicable.

TABLE C-56b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing East With Water Sprays
Product: R-11 Building Insulation
(Metric)

Run number:	1*	2	3	Avg.
Date	07/15/81	07/15/81	07/16/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	91	91	91	--
Moisture, % by volume	4.09	4.02	4.14	4.08
Avg. stack temperture, °C	124.7	124.2	123.2	123.7
Isokinetic, %	111.9	103.8	98.1	101.0
Volume of gas sampled, Nm^3	2.044	2.069	1.938	2.004
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	70.90	82.10	51.50	66.80
Concentration, mg/Nm^3	34.61	39.59	26.52	33.06
Emission level, kg/Mg	0.87	1.09	0.73	0.91
Phenolic compounds				
Mass collected, mg	10.80	9.80	9.90	9.9
Concentration, mg/Nm^3	5.27	4.73	5.10	4.92
Emission level, kg/Mg	0.14	0.13	0.14	0.14
Phenol				
Mass collected, mg	1.80	0.60	1.30	0.95
Concentration, mg/Nm^3	0.88	0.29	0.67	0.48
Emission level, kg/Mg	0.02	0.01	0.02	0.02
Formaldehyde				
Mass collected, mg	9.30	17.10	9.20	13.15
Concentration, mg/Nm^3	4.54	8.25	4.74	6.50
Emission level, kg/Mg	0.12	0.23	0.13	0.18

*Data excluded from average.
N/A = Not applicable.

TABLE C-57a. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing West With Water Sprays
Product: R-11 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	07/15/81	07/15/81	07/16/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	91	91	91	--
Moisture, % by volume	3.71	3.73	4.34	3.93
Avg. stack temperature, °F	273.8	269.7	258.9	267.5
Isokinetic, %	101.6	100.1	94.6	98.8
Volume of gas sampled, dscf	73.207	75.922	71.834	73.654
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, gr	1.511	3.040	1.471	2.007
Concentration, gr/dscf	0.021	0.040	0.021	0.027
Emission level, lb/ton	1.82	3.72	1.91	2.48
Phenolic compounds				
Mass collected, gr	0.117	0.105	0.200	0.141
Concentration, gr/dscf	0.002	0.001	0.003	0.002
Emission level, lb/ton	0.14	0.13	0.26	0.18
Phenol				
Mass collected, gr	0.023	0.006	0.022	0.017
Concentration, gr/dscf	0.000	0.000	0.000	0.000
Emission level, lb/ton	0.03	0.01	0.03	0.02
Formaldehyde				
Mass collected, gr	0.302	0.259	0.185	0.249
Concentration, gr/dscf	0.004	0.003	0.003	0.003
Emission level, lb/ton	0.36	0.32	0.24	0.31

N/A = Not applicable.

TABLE C-57b. SUMMARY OF TEST RESULTS--LINE J
Sampling Location: Curing West With Water Sprays
Product: R-11 Building Insulation
(Metric)

Run number:	1	2	3	Avg.
Date	07/15/81	07/15/81	07/16/81	--
Sampling time, min	126	126	126	--
Glass pull rate, % of design	91	91	91	--
Moisture, % by volume	3.71	3.73	4.34	3.93
Avg. stack temperture, °C	134.3	132.0	126.1	130.8
Isokinetic, %	101.6	100.1	94.6	98.8
Volume of gas sampled, Nm^3	2.073	2.150	2.034	2.086
Opacity average, %	N/A	N/A	N/A	--
Particulate matter				
Mass collected, mg	98.10	197.40	95.50	130.33
Concentration, mg/Nm^3	47.22	91.63	46.85	61.90
Emission level, kg/Mg	0.91	1.86	0.96	1.24
Phenolic compounds				
Mass collected, mg	7.60	6.80	13.00	9.13
Concentration, mg/Nm^3	3.66	3.16	6.38	4.40
Emission level, kg/Mg	0.07	0.07	0.13	0.09
Phenol				
Mass collected, mg	1.50	0.40	1.40	1.10
Concentration, mg/Nm^3	0.72	0.19	0.69	0.532
Emission level, kg/Mg	0.02	0.01	0.02	0.02
Formaldehyde				
Mass collected, mg	19.60	16.80	12.00	16.13
Concentration, mg/Nm^3	9.44	7.80	5.89	7.71
Emission level, kg/Mg	0.18	0.16	0.12	0.15

N/A = Not applicable.

TABLE C-58a. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming North
Product: Uncured Pipe Insulation
(English)

Run number:	1X	2X	3X	Avg.
Date	05/27/81	05/28/81	05/28/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	120	119	--
Moisture, % by volume	4.03	3.57	4.04	3.88
Avg. stack temperature, °F	156.9	140.7	144.1	147.2
Isokinetic, %	103.1	100.2	99.8	101.0
Volume of gas sampled, dscf	78.329	82.423	81.353	80.702
Opacity average, %	29	3	1	--
Particulate matter				
Mass collected, gr	2.851	1.796	1.628	2.092
Concentration, gr/dscf	0.036	0.022	0.020	0.026
Emission level, lb/ton	47.35	29.43	26.85	34.54
Phenolic compounds				
Mass collected, gr	1.203	0.721	1.027	0.984
Concentration, gr/dscf	0.016	0.009	0.013	0.012
Emission level, lb/ton	20.23	11.81	16.94	16.33
Phenol				
Mass collected, gr	0.488	0.277	0.417	0.394
Concentration, gr/dscf	0.006	0.003	0.005	0.005
Emission level, lb/ton	8.11	4.54	6.88	6.51
Formaldehyde				
Mass collected, gr	0.116	0.076	0.131	0.107
Concentration, gr/dscf	0.002	0.001	0.002	0.003
Emission level, lb/ton	1.92	1.24	2.16	1.77

TABLE C-58b. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming North
Product: Uncured Pipe Insulation
(Metric)

Run number:	1X	2X	3X	Avg.
Date	05/27/81	05/28/81	05/28/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	120	119	--
Moisture, % by volume	4.03	3.57	4.04	3.88
Avg. stack temperture, °C	69.4	60.4	62.3	64.03
Isokinetic, %	103.1	100.2	99.8	101.0
Volume of gas sampled, Nm^3	2.218	2.334	2.304	2.285
Opacity average, %	29	3	1	--
Particulate matter				
Mass collected, mg	185.10	116.60	105.70	135.80
Concentration, mg/Nm^3	83.28	49.85	45.79	59.64
Emission level, kg/Mg	23.68	14.72	13.43	17.27
Phenolic compounds				
Mass collected, mg	79.10	46.80	66.70	64.2
Concentration, mg/Nm^3	35.59	20.01	28.89	28.16
Emission level, kg/Mg	10.12	10.91	8.47	8.17
Phenol				
Mass collected, mg	31.70	18.00	27.10	25.60
Concentration, mg/Nm^3	14.26	7.70	11.74	11.23
Emission level, kg/Mg	4.06	2.27	3.44	3.26
Formaldehyde				
Mass collected, mg	7.50	4.90	8.50	6.97
Concentration, mg/Nm^3	3.37	2.10	3.68	3.05
Emission level, kg/Mg	0.96	0.62	1.08	0.89

TABLE C-59a. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming South
Product: Uncured Pipe Insulation
(English)

Run number:	1X	2X	3X	Avg.
Date	05/27/81	05/28/81	05/28/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	120	119	--
Moisture, % by volume	3.63	3.46	3.58	3.56
Avg. stack temperature, °F	157.4	140.0	147.5	148.3
Isokinetic, %	98.3	96.3	96.5	97.0
Volume of gas sampled, dscf	93.246	98.862	98.702	96.937
Opacity average, %	18	3	0	--
Particulate matter				
Mass collected, gr	2.675	1.332	1.614	1.874
Concentration, gr/dscf	0.029	0.014	0.016	0.020
Emission level, lb/ton	45.12	21.99	26.67	31.26
Phenolic compounds				
Mass collected, gr	1.261	0.693	1.004	0.986
Concentration, gr/dscf	0.014	0.007	0.010	0.010
Emission level, lb/ton	21.27	11.44	16.59	16.43
Phenol				
Mass collected, gr	0.444	0.236	0.299	0.326
Concentration, gr/dscf	0.005	0.002	0.003	0.003
Emission level, lb/ton	7.48	3.89	4.94	5.44
Formaldehyde				
Mass collected, gr	0.097	0.086	0.131	0.105
Concentration, gr/dscf	0.001	0.001	0.001	0.001
Emission level, lb/ton	1.64	1.42	2.16	1.74

TABLE C-59b. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming South
Product: Uncured Pipe Insulation
(Metric)

Run number:	1X	2X	3X	Avg.
Date	05/27/81	05/28/81	05/28/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	120	119	--
Moisture, % by volume	3.63	3.46	3.58	3.56
Avg. stack temperture, °C	69.7	60.0	64.2	64.33
Isokinetic, %	98.3	96.3	96.5	97.0
Volume of gas sampled, Nm^3	2.640	2.799	2.795	2.745
Opacity average, %	18	3	0	--
Particulate matter				
Mass collected, mg	173.70	86.50	104.80	121.67
Concentration, mg/Nm^3	65.65	30.83	37.42	44.63
Emission level, kg/Mg	22.56	11.00	13.34	15.63
Phenolic compounds				
Mass collected, mg	81.90	45.00	65.20	64.03
Concentration, mg/Nm^3	30.95	16.04	23.28	23.42
Emission level, kg/Mg	10.64	5.72	8.30	8.22
Phenol				
Mass collected, mg	28.80	15.30	19.40	21.17
Concentration, mg/Nm^3	10.88	5.45	6.93	7.76
Emission level, kg/Mg	3.74	1.95	2.57	2.72
Formaldehyde				
Mass collected, mg	6.30	5.60	8.50	6.80
Concentration, mg/Nm^3	2.38	2.00	3.04	2.47
Emission level, kg/Mg	0.82	0.71	1.08	0.87

TABLE C-60a. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming North
Product: Flexible Duct
(English)

Run number:	1	2	3	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	4.30	3.82	4.48	4.20
Avg. stack temperature, °F	165.7	163.1	165.1	164.6
Isokinetic, %	105.9	103.4	104.8	104.7
Volume of gas sampled, dscf	73.463	72.879	72.022	72.788
Opacity average, %	3	0	8	--
Particulate matter				
Mass collected, gr	2.898	2.082	1.702	2.227
Concentration, gr/dscf	0.040	0.029	0.024	0.306
Emission level, lb/ton	46.72	34.40	27.88	36.33
Phenolic compounds				
Mass collected, gr	1.207	0.924	0.665	0.932
Concentration, gr/dscf	0.016	0.013	0.009	0.013
Emission level, lb/ton	19.46	15.27	10.90	15.21
Phenol				
Mass collected, gr	0.360	0.291	0.236	0.296
Concentration, gr/dscf	0.005	0.004	0.003	0.004
Emission level, lb/ton	5.81	4.81	3.86	4.83
Formaldehyde				
Mass collected, gr	0.211	0.188	0.132	0.177
Concentration, gr/dscf	0.003	0.003	0.002	0.003
Emission level, lb/ton	3.40	3.10	2.17	2.89

TABLE C-60b. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming North
Product: Flexible Duct
(Metric)

Run number:	1	2	3	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	4.30	3.82	4.48	4.20
Avg. stack temperture, °C	74.3	72.9	73.9	73.7
Isokinetic, %	105.9	103.4	104.8	104.7
Volume of gas sampled, Nm^3	2.080	2.064	2.039	2.174
Opacity average, %	3	0	8	--
Particulate matter				
Mass collected, mg	188.20	135.20	110.50	144.63
Concentration, mg/Nm^3	90.28	65.38	54.07	69.91
Emission level, kg/Mg	23.36	17.20	13.94	18.17
Phenolic compounds				
Mass collected, mg	78.40	60.00	43.20	60.53
Concentration, mg/Nm^3	37.61	29.01	21.14	29.25
Emission level, kg/Mg	9.73	7.64	5.45	7.61
Phenol				
Mass collected, mg	23.40	18.90	15.30	19.20
Concentration, mg/Nm^3	11.23	9.14	7.49	9.28
Emission level, kg/Mg	2.91	2.41	1.93	2.43
Formaldehyde				
Mass collected, mg	13.70	12.20	8.60	11.50
Concentration, mg/Nm^3	6.57	5.90	4.21	5.56
Emission level, kg/Mg	1.70	1.55	1.09	1.45

TABLE C-61a. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming South
Product: Flexible Duct
(English)

Run number:	1	2	3	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	3.34	4.09	4.46	3.96
Avg. stack temperature, °F	170.2	158.9	165.6	164.9
Isokinetic, %	101.4	101.3	100.7	101.1
Volume of gas sampled, dscf	90.60	91.046	91.166	90.937
Opacity average, %	2	0	8	--
Particulate matter				
Mass collected, gr	2.823	2.093	1.964	2.293
Concentration, gr/dscf	0.031	0.023	0.022	0.025
Emission level, lb/ton	46.06	34.19	32.43	37.56
Phenolic compounds				
Mass collected, gr	1.169	1.050	0.944	1.054
Concentration, gr/dscf	0.013	0.012	0.010	0.012
Emission level, lb/ton	19.07	17.16	15.59	17.27
Phenol				
Mass collected, gr	0.345	0.350	0.288	0.328
Concentration, gr/dscf	0.004	0.004	0.003	0.004
Emission level, lb/ton	5.63	5.71	4.76	5.37
Formaldehyde				
Mass collected, gr	0.189	0.219	0.157	0.188
Concentration, gr/dscf	0.002	0.002	0.002	0.002
Emission level, lb/ton	3.09	3.57	2.59	3.08

TABLE C-61b. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Forming South
Product: Flexible Duct
(Metric)

Run number:	1	2	3	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	144	144	144	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	3.34	4.09	4.46	3.96
Avg. stack temperture, °C	76.8	70.5	74.2	73.83
Isokinetic, %	101.4	101.3	100.7	101.1
Volume of gas sampled, Nm^3	2.565	2.578	2.581	2.575
Opacity average, %	2	0	8	--
Particulate matter				
Mass collected, mg	183.30	135.90	127.50	148.90
Concentration, mg/Nm^3	71.30	52.60	49.29	57.73
Emission level, kg/Mg	23.03	17.10	16.22	18.78
Phenolic compounds				
Mass collected, mg	75.90	68.20	61.30	68.47
Concentration, mg/Nm^3	29.52	26.40	23.70	26.54
Emission level, kg/Mg	9.54	8.58	7.80	8.64
Phenol				
Mass collected, mg	22.40	22.70	18.70	21.27
Concentration, mg/Nm^3	8.71	8.79	7.23	8.24
Emission level, kg/Mg	2.82	2.86	2.38	2.69
Formaldehyde				
Mass collected, mg	12.30	14.20	10.20	12.23
Concentration, mg/Nm^3	4.78	5.50	3.94	4.74
Emission level, kg/Mg	1.55	1.79	1.30	1.54

TABLE C-62a. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Curing-East
Product: Flexible Duct
(English)

Run number:	1	2	3	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	3.99	4.09	4.71	4.26
Avg. stack temperature, °F	347.0	351.3	346.9	348.4
Isokinetic, %	97.0	92.9	95.4	95.1
Volume of gas sampled, dscf	87.319	85.944	89.829	87.697
Opacity average, %	4	5	5	--
Particulate matter				
Mass collected, gr	3.881	3.507	2.906	3.431
Concentration, gr/dscf	0.044	0.041	0.032	0.039
Emission level, lb/ton	3.18	3.00	2.43	2.87
Phenolic compounds				
Mass collected, gr	0.407	0.461	0.519	0.462
Concentration, gr/dscf	0.005	0.005	0.006	0.005
Emission level, lb/ton	0.33	0.39	0.44	0.39
Phenol				
Mass collected, gr	0.062	0.055	0.051	0.056
Concentration, gr/dscf	0.001	0.001	0.001	0.001
Emission level, lb/ton	0.05	0.05	0.04	0.05
Formaldehyde				
Mass collected, gr	0.408	0.089	0.607	0.368
Concentration, gr/dscf	0.005	0.001	0.007	0.004
Emission level, lb/ton	0.34	0.08	0.51	0.31

TABLE C-62b. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Curing-East
Product: Flexible Duct
(Metric)

Run number:	1	2	3	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	3.99	4.09	4.71	4.26
Avg. stack temperture, °C	175.0	177.4	174.9	175.8
Isokinetic, %	97.0	92.9	95.4	95.1
Volume of gas sampled, Nm^3	2.473	2.434	2.544	2.484
Opacity average, %	4	5	5	--
Particulate matter				
Mass collected, mg	252.00	227.70	188.70	222.80
Concentration, mg/Nm^3	101.70	93.37	74.03	89.70
Emission level, kg/Mg	1.59	1.50	1.22	1.44
Phenolic compounds				
Mass collected, mg	26.40	29.90	33.70	30.00
Concentration, mg/Nm^3	10.66	12.26	13.22	12.05
Emission level, kg/Mg	0.17	0.20	0.22	0.20
Phenol				
Mass collected, mg	4.00	3.60	3.30	3.63
Concentration, mg/Nm^3	1.61	1.48	1.30	1.46
Emission level, kg/Mg	0.03	0.03	0.02	0.03
Formaldehyde				
Mass collected, mg	26.50	5.80	39.40	23.90
Concentration, mg/Nm^3	10.70	2.38	15.46	9.51
Emission level, kg/Mg	0.17	0.04	0.26	0.16

TABLE C-63a. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Curing-West
Product: Flexible Duct
(English)

Run number:	1	2	3*	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	3.74	3.51	4.31	3.63
Avg. stack temperature, °F	308.1	308.0	295.1	308.1
Isokinetic, %	96.3	98.0	96.7	97.2
Volume of gas sampled, dscf	84.923	94.843	94.080	89.883
Opacity average, %	15	15	4	--
Particulate matter				
Mass collected, gr	6.051	6.103	3.581	6.077
Concentration, gr/dscf	0.071	0.064	0.038	0.068
Emission level, lb/ton	8.98	8.89	5.32	8.94
Phenolic compounds				
Mass collected, gr	1.910	2.179	1.406	2.045
Concentration, gr/dscf	0.023	0.023	0.015	0.023
Emission level, lb/ton	2.83	3.18	2.09	3.01
Phenol				
Mass collected, gr	0.262	0.288	0.254	0.275
Concentration, gr/dscf	0.003	0.003	0.003	0.003
Emission level, lb/ton	0.39	0.42	0.38	0.41
Formaldehyde				
Mass collected, gr	0.484	0.431	0.590	0.458
Concentration, gr/dscf	0.006	0.005	0.006	0.006
Emission level, lb/ton	0.72	0.63	0.88	0.68

*Data excluded from average.

TABLE C-63b. SUMMARY OF TEST RESULTS--LINE K
Sampling Location: Curing-West
Product: Flexible Duct
(Metric)

Run number:	1	2	3*	Avg.
Date	05/29/81	05/29/81	05/30/81	--
Sampling time, min	160	160	160	--
Glass pull rate, % of design	115	115	115	--
Moisture, % by volume	3.74	3.51	4.31	3.63
Avg. stack temperture, °C	153.4	153.3	146.2	153.4
Isokinetic, %	96.3	98.0	96.7	97.2
Volume of gas sampled, Nm^3	2.405	2.686	2.664	2.546
Opacity average, %	15	15	4	--
Particulate matter				
Mass collected, mg	392.90	396.30	232.50	394.6
Concentration, mg/Nm^3	163.04	147.25	87.09	155.15
Emission level, kg/Mg	4.49	4.45	2.66	4.47
Phenolic compounds				
Mass collected, mg	124.00	141.51	91.30	132.75
Concentration, mg/Nm^3	51.46	52.58	34.20	52.02
Emission level, kg/Mg	1.42	1.59	1.05	1.51
Phenol				
Mass collected, mg	17.00	18.70	16.50	17.85
Concentration, mg/Nm^3	7.05	6.95	6.18	7.00
Emission level, kg/Mg	0.20	0.21	0.19	0.21
Formaldehyde				
Mass collected, mg	31.40	28.00	38.30	29.70
Concentration, mg/Nm^3	13.03	10.40	14.35	11.72
Emission level, kg/Mg	0.36	0.32	0.44	0.34

*Data excluded from average.

TABLE C-64a. SUMMARY OF TEST RESULTS--LINE L

Sampling Location: Forming Scrubber Inlet

Product: R-19 Building Insulation

(English)

Run number:	1*	2	3	4	Avg.
Date	09/28/82	09/28/82	09/28/82	09/29/82	--
Sampling time, min	--	113	108	108	--
Glass pull rate, % of design	--	100	100	100	--
Moisture, % by volume	--	13.74	13.06	11.43	12.74
Avg. stack temperature, °F	--	126.0	127.9	126.0	126.6
Isokinetic, %	--	107.7	95.3	106.8	--
Volume of gas sampled, dscf	--	40.607	40.960	41.314	40.960
Opacity average, %	--	24	22	21	--
Particulate matter					
Mass collected, gr	--	1.614	2.252	2.446	2.104
Concentration, gr/dscf	--	0.040	0.055	0.059	0.051
Emission level, lb/ton	--	4.90	8.06	7.78	6.91
Phenolic compounds					
Mass collected, gr	--	0.533	0.974	0.881	0.796
Concentration, gr/dscf	--	0.013	0.024	0.021	0.019
Emission level, lb/ton	--	1.62	3.48	2.80	2.63
Phenol					
Mass collected, gr	--	0.245	0.368	0.361	0.325
Concentration, gr/dscf	--	0.006	0.009	0.009	0.008
Emission level, lb/ton	--	0.74	1.32	1.16	1.07
Formaldehyde					
Mass collected, gr	--	0.344	0.483	0.485	0.437
Concentration, gr/dscf	--	0.008	0.012	0.012	0.011
Emission level, lb/ton	--	1.04	1.72	1.54	1.43

*Void test run

TABLE C-64b. SUMMARY OF TEST RESULTS--LINE L

Sampling Location: Forming Scrubber Inlet

Product: R-19 Building Insulation

(Metric)

Run number:	1*	2	3	4	Avg.
Date	09/28/82	09/28/82	09/28/82	09/29/82	--
Sampling time, min	--	113	108	108	--
Glass pull rate, % of design	--	100	100	100	--
Moisture, % by volume	--	13.74	13.06	11.43	12.74
Avg. stack temperature, °C	--	52.2	53.3	52.2	52.6
Isokinetic, %	--	107.7	95.3	100.6	--
Volume of gas sampled, Nm^3	--	1.15	1.16	1.17	1.16
Opacity average, %	--	24	22	21	--
Particulate matter					
Mass collected, mg	--	104.70	146.06	158.64	136.47
Concentration, mg/Nm^3	--	90.97	125.99	135.78	117.58
Emission level, kg/Mg	--	2.45	4.03	3.89	3.46
Phenolic compounds					
Mass collected, mg	--	34.58	63.14	57.15	51.62
Concentration, mg/Nm^3	--	30.07	54.43	48.85	44.45
Emission level, kg/Mg	--	0.81	1.74	1.40	1.32
Phenol					
Mass collected, mg	--	15.92	23.85	23.39	21.05
Concentration, mg/Nm^3	--	13.84	20.56	19.99	18.13
Emission level, kg/Mg	--	0.37	0.66	0.58	0.54
Formaldehyde					
Mass collected, mg	--	22.31	31.30	31.48	28.36
Concentration, mg/Nm^3	--	19.40	26.98	26.91	24.43
Emission level, kg/Mg	--	0.52	0.86	0.77	0.72

*Void test run

TABLE C-65a. SUMMARY OF TEST RESULTS--LINE L

Sampling Location: Forming "25" Scrubber Outlet

Product: R-19 Building Insulation

(English)

Run number:	1*	2	3	4	Avg.
Date	09/28/82	09/28/82	09/29/82	09/29/82	--
Sampling time, min	--	100	100	100	--
Glass pull rate, % of design	--	100	100	100	--
Moisture, % by volume	--	14.5	13.4	14.9	14.3
Avg. stack temperature, °F	--	126.0	124.0	126.0	125.3
Isokinetic, %	--	102.6	102.9	102.5	--
Volume of gas sampled, dscf	--	64.972	64.972	63.206	64.383
Opacity average, %	--	22	21	24	--
Particulate matter					
Mass collected, gr	--	2.084	1.564	1.493	1.714
Concentration, gr/dscf	--	0.032	0.024	0.024	0.027
Emission level, lb/ton	--	0.92	0.68	0.66	0.75
Phenolic compounds					
Mass collected, gr	--	0.985	0.902	0.910	0.932
Concentration, gr/dscf	--	0.015	0.014	0.014	0.014
Emission level, lb/ton	--	0.44	0.40	0.40	0.41
Phenol					
Mass collected, gr	--	0.689	0.796	0.688	0.724
Concentration, gr/dscf	--	0.011	0.012	0.011	0.011
Emission level, lb/ton	--	0.30	0.34	0.30	0.31
Formaldehyde					
Mass collected, gr	--	0.540	0.458	0.569	0.522
Concentration, gr/dscf	--	0.008	0.007	0.009	0.008
Emission level, lb/ton	--	0.24	0.20	0.24	0.23

*Void test run

TABLE C-65b. SUMMARY OF TEST RESULTS--LINE L
Sampling Location: Forming "25" Scrubber Outlet
Product: R-19 Building Insulation
(Metric)

Run number:	1*	2	3	4	Avg.
Date	09/28/82	09/28/82	09/29/82	09/29/82	--
Sampling time, min	--	100	100	100	--
Glass pull rate, % of design	--	100	100	100	--
Moisture, % by volume	--	14.5	13.4	14.9	14.3
Avg. stack temperature, °C	--	52.2	51.1	52.2	51.8
Isokinetic, %	--	102.6	102.9	102.5	--
Volume of gas sampled, Nm^3	--	1.84	1.84	1.79	1.82
Opacity average, %	--	22	21	24	--
Particulate matter					
Mass collected, mg	--	135.14	101.46	96.80	111.13
Concentration, mg/Nm^3	--	73.36	55.15	54.13	60.88
Emission level, kg/Mg	--	0.46	0.34	0.33	0.38
Phenolic compounds					
Mass collected, mg	--	63.90	58.50	59.04	60.48
Concentration, mg/Nm^3	--	34.73	31.79	32.98	33.17
Emission level, kg/Mg	--	0.22	0.20	0.20	0.21
Phenol					
Mass collected, mg	--	44.67	51.62	44.65	46.98
Concentration, mg/Nm^3	--	24.28	28.05	24.94	25.76
Emission level, kg/Mg	--	0.15	0.17	0.15	0.16
Formaldehyde					
Mass collected, mg	--	35.05	29.68	36.88	33.87
Concentration, mg/Nm^3	--	19.05	16.13	20.60	18.59
Emission level, kg/Mg	--	0.12	0.10	0.12	0.11

*Void test run

TABLE C-66a. SUMMARY OF TEST RESULTS--LINE L
Sampling Location: Forming "50" Scrubber Outlet
Product: R-19 Building Insulation
(English)

Run number:	1	2	3*	4	Avg.
Date	09/28/82	09/28/82	09/29/82	09/29/82	--
Sampling time, min	100	100	100	100	--
Glass pull rate, % of design	100	100	100	100	--
Moisture, % by volume	14.0	15.1	13.8	15.1	14.7
Avg. stack temperature, °F	61.7	63.3	59.4	62.8	62.6
Isokinetic, %	104.2	104.5	103.2	102.7	--
Volume of gas sampled, dscf	54.732	56.850	58.969	55.085	55.556
Opacity average, %	24	22	21	24	--
Particulate matter					
Mass collected, gr	1.410	1.471	2.534	1.264	1.382
Concentration, gr/dscf	0.026	0.026	0.043	0.023	0.025
Emission level, lb/ton	1.06	1.10	1.92	1.44	1.20
Phenolic compounds					
Mass collected, gr	0.689	0.765	0.739	0.800	0.751
Concentration, gr/dscf	0.013	0.013	0.013	0.015	0.014
Emission level, lb/ton	0.52	0.58	0.56	0.62	0.57
Phenol					
Mass collected, gr	0.460	0.612	0.683	0.627	0.566
Concentration, gr/dscf	0.008	0.011	0.012	0.011	0.010
Emission level, lb/ton	0.34	0.46	0.52	0.48	0.43
Formaldehyde					
Mass collected, gr	0.400	0.461	0.391	0.486	0.449
Concentration, gr/dscf	0.007	0.008	0.007	0.009	0.008
Emission level, lb/ton	0.30	0.34	0.30	0.38	0.34

*Data excluded from average.

TABLE C-66b. SUMMARY OF TEST RESULTS--LINE L
Sampling Location: Forming "50" Scrubber Outlet
Product: R-19 Building Insulation
(Metric)

Run number:	1	2	3*	4	Avg.
Date	09/28/82	09/28/82	09/29/82	09/29/82	--
Sampling time, min	100	100	100	100	--
Glass pull rate, % of design	100	100	100	100	--
Moisture, % by volume	14.0	15.1	13.8	15.1	14.7
Avg. stack temperature, °C	61.7	63.3	59.4	62.8	62.6
Isokinetic, %	104.2	104.5	103.2	102.7	--
Volume of gas sampled, Nm^3	1.55	1.61	1.67	1.56	1.57
Opacity average, %	24	22	21	24	--
Particulate matter					
Mass collected, mg	91.44	95.38	164.33	121.80	102.87
Concentration, mg/Nm^3	59.12	59.20	98.49	78.16	65.49
Emission level, kg/Mg	0.53	0.55	0.96	0.72	0.60
Phenolic compounds					
Mass collected, mg	44.71	49.63	47.91	51.89	48.74
Concentration, mg/Nm^3	28.85	30.83	28.69	33.26	30.98
Emission level, kg/Mg	0.26	0.29	0.28	0.31	0.29
Phenol					
Mass collected, mg	29.85	39.03	44.28	40.66	36.51
Concentration, mg/Nm^3	19.26	24.24	26.51	26.06	23.19
Emission level, kg/Mg	0.17	0.23	0.26	0.24	0.21
Formaldehyde					
Mass collected, mg	25.95	29.89	25.39	31.54	29.13
Concentration, mg/Nm^3	16.74	18.57	15.20	20.22	18.51
Emission level, kg/Mg	0.15	0.17	0.15	0.19	0.17

*Data excluded from average.

TABLE C-67a. SUMMARY OF TEST RESULTS--LINE L
Sampling Location: Curing/Cooling Scrubber Inlet
Product: R-19 Building Insulation
(English)

Run number:	1	2	3	Avg.
Date	09/30/82	09/30/82	09/30/82	--
Sampling time, min	80	80	80	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	10.5	10.2	9.7	10.1
Avg. stack temperature, °F	116.1	115.0	113.0	114.7
Isokinetic, %	98.5	100.8	96.7	--
Volume of gas sampled, dscf	50.141	48.023	45.904	48.023
Opacity average, %	21	22	--	--
Particulate matter				
Mass collected, gr	4.116	3.367	3.197	3.560
Concentration, gr/dscf	0.082	0.070	0.070	0.074
Emission level, lb/ton	1.98	1.58	1.56	1.71
Phenolic compounds				
Mass collected, gr	0.767	0.733	0.687	0.729
Concentration, gr/dscf	0.015	0.015	0.015	0.015
Emission level, lb/ton	0.38	0.34	0.34	0.35
Phenol				
Mass collected, gr	0.434	0.361	0.387	0.394
Concentration, gr/dscf	0.009	0.008	0.008	0.008
Emission level, lb/ton	0.20	0.16	0.18	0.18
Formaldehyde				
Mass collected, gr	0.450	0.442	0.454	0.449
Concentration, gr/dscf	0.009	0.009	0.010	0.009
Emission level, lb/ton	0.22	0.20	0.22	0.21

TABLE C-67b. SUMMARY OF TEST RESULTS--LINE L

Sampling Location: Curing/Cooling Scrubber Inlet

Product: R-19 Building Insulation

(Metric)

Run number:	1	2	3	Avg.
Date	09/30/82	09/30/82	09/30/82	--
Sampling time, min	80	80	80	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	10.5	10.2	9.7	10.1
Avg. stack temperature, °C	46.7	46.1	45.0	45.9
Isokinetic, %	98.5	100.8	96.7	--
Volume of gas sampled, Nm^3	1.42	1.36	1.30	1.36
Opacity average, %	21	22	--	--
Particulate matter				
Mass collected, mg	266.92	218.40	207.34	230.89
Concentration, mg/Nm^3	187.87	160.78	159.50	169.38
Emission level, kg/Mg	0.99	0.79	0.78	0.85
Phenolic compounds				
Mass collected, mg	49.76	47.52	44.54	47.27
Concentration, mg/Nm^3	35.04	34.94	34.26	34.75
Emission level, kg/Mg	0.19	0.17	0.17	0.18
Phenol				
Mass collected, mg	28.15	23.42	25.07	25.55
Concentration, mg/Nm^3	19.82	17.22	19.28	18.77
Emission level, kg/Mg	0.10	0.08	0.09	0.09
Formaldehyde				
Mass collected, mg	29.19	28.66	29.42	29.09
Concentration, mg/Nm^3	20.56	21.07	22.63	21.42
Emission level, kg/Mg	0.11	0.10	0.11	0.11

TABLE C-68a. SUMMARY OF TEST RESULTS--LINE L

Sampling Location: Curing/Cooling Scrubber Outlet

Product: R-19 Building Insulation

(English)

Run number:	1	2	3	Avg.
Date	09/30/82	09/30/82	09/30/82	--
Sampling time, min	100	100	100	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	12.7	12.9	12.3	12.6
Avg. stack temperature, °F	120.0	122.0	120.0	120.7
Isokinetic, %	103.6	97.0	98.4	--
Volume of gas sampled, dscf	55.085	75.918	86.158	72.387
Opacity average, %	21	22	--	--
Particulate matter				
Mass collected, gr	0.746	2.045	2.213	1.668
Concentration, gr/dscf	0.014	0.027	0.026	0.022
Emission level, lb/ton	0.32	0.64	0.66	0.54
Phenolic compounds				
Mass collected, gr	0.311	0.780	0.849	0.647
Concentration, gr/dscf	0.006	0.010	0.010	0.009
Emission level, lb/ton	0.14	0.24	0.26	0.21
Phenol				
Mass collected, gr	0.272	0.588	0.652	0.504
Concentration, gr/dscf	0.005	0.008	0.008	0.007
Emission level, lb/ton	0.12	0.18	0.20	0.17
Formaldehyde				
Mass collected, gr	0.172	0.446	0.549	0.389
Concentration, gr/dscf	0.003	0.006	0.006	0.005
Emission level, lb/ton	0.08	0.14	0.16	0.13

TABLE C-68b. SUMMARY OF TEST RESULTS--LINE L

Sampling Location: Curing/Cooling Scrubber Outlet

Product: R-19 Building Insulation

(Metric)

Run number:	1	2	3	Avg.
Date	09/30/82	09/30/82	09/30/82	--
Sampling time, min	100	100	100	--
Glass pull rate, % of design	102	102	102	--
Moisture, % by volume	12.7	12.9	12.3	12.6
Avg. stack temperature, °C	48.9	50.0	48.9	49.3
Isokinetic, %	103.6	97.0	98.4	--
Volume of gas sampled, Nm^3	1.56	2.15	2.44	2.05
Opacity average, %	21	22	--	--
Particulate matter				
Mass collected, mg	48.40	132.64	143.56	108.20
Concentration, mg/Nm^3	31.06	61.69	58.82	50.52
Emission level, kg/Mg	0.16	0.32	0.33	0.27
Phenolic compounds				
Mass collected, mg	20.18	50.60	55.05	41.94
Concentration, mg/Nm^3	12.94	23.53	22.56	19.68
Emission level, kg/Mg	0.07	0.12	0.13	0.11
Phenol				
Mass collected, mg	17.67	38.16	42.27	32.70
Concentration, mg/Nm^3	11.33	17.75	17.32	15.47
Emission level, kg/Mg	0.06	0.09	0.10	0.08
Formaldehyde				
Mass collected, mg	11.18	28.94	35.60	24.82
Concentration, mg/Nm^3	7.17	13.46	14.59	11.74
Emission level, kg/Mg	0.04	0.07	0.08	0.06

TABLE C-69. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	09/22/81
Type of plant	Rotary spin
Distance from observer to discharge point	1,300 ft at location 1; 1,800 ft at 2
Location of discharge	Wet ESP outlet
Height of observation point	Roof at location 1; ground level at 2
Height of point of discharge	100 ft at both locations
Direction of observer from discharge point	SW at both locations
Description of background	Blue sky at both locations
Description of sky	5% overcast
Wind direction	N to S
Wind velocity	5-10 mph
Color of plume	Gray-green
Duration of observation	18 min at location 1; 96 min at location 2

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	02:55 p.m.	03:00 p.m.	10	10
2	03:01	03:06	10	10
3	03:07	03:12	10	10
4	03:17	03:22	10	9
5	03:23	03:28	10	10
6	03:29	03:34	10	10
7	03:35	03:40	10	8
8	03:41	03:46	10	8
9	03:47	03:52	10	8
10	04:25	04:30	10	10
11	04:31	04:36	10	10
12	04:37	04:42	10	10
13	04:43	04:48	10	10
14	04:49	04:54	10	9
15	04:55	05:00	10	10
16	05:01	05:06	10	10
17	05:07	05:12	10	9
18	05:13	05:18	10	10
19	05:19	05:24	10	10

SUMMARY OF VISIBLE EMISSIONS

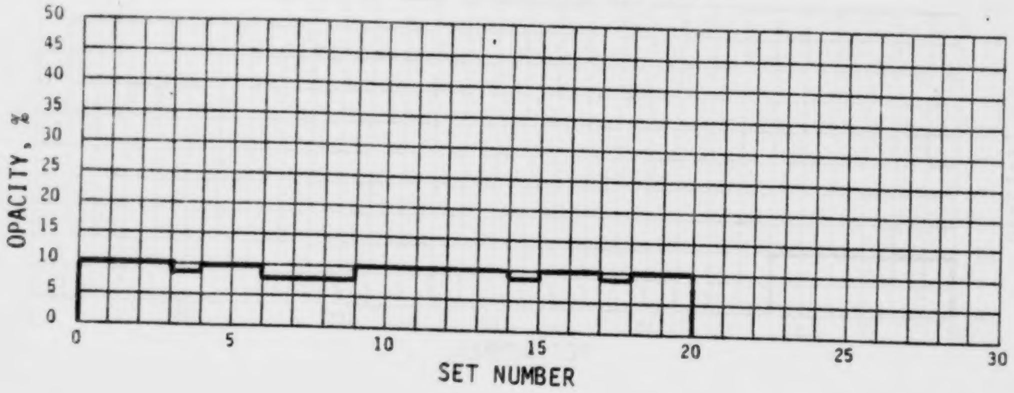


TABLE C-70. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	09/23/81
Type of plant	Rotary spin
Distance from observer to discharge point	800 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	100 ft
Direction of observer from discharge point	E
Description of background	Blue sky
Description of sky	Clear
Wind direction	N to S
Wind velocity	5-10 mph
Color of plume	Gray-green
Duration of observation	36 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:30 a.m.	10:35 a.m.	10	10
2	10:36	10:41	10	10
3	10:42	10:47	10	10
4	10:48	10:53	10	10
5	10:59	11:04	10	10
6	11:11	11:16	10	10

SUMMARY OF VISIBLE EMISSIONS

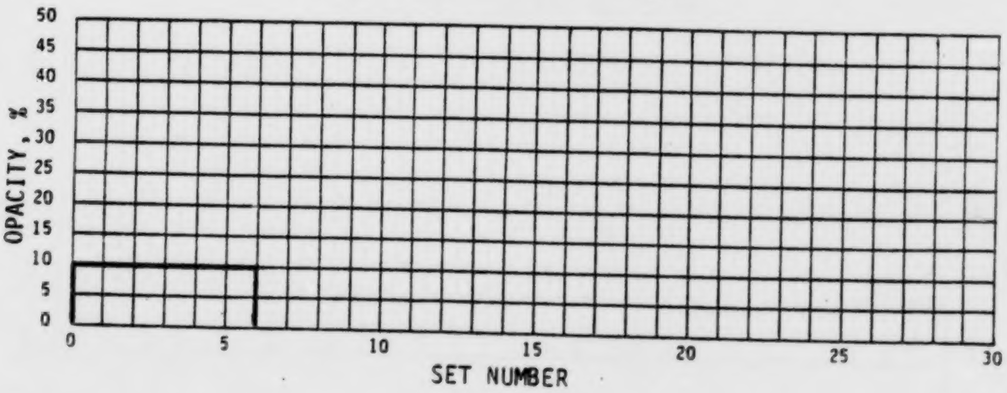


TABLE C-71. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	09/23/81
Type of plant	Rotary spin
Distance from observer to discharge point	200 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	100 ft
Direction of observer from discharge point	N
Description of background	Blue sky
Description of sky	Clear
Wind direction	N to S
Wind velocity	5-10 mph
Color of plume	Gray-green
Duration of observation	90 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	02:10 p.m.	02:15 p.m.	10	10
2	02:16	02:21	10	10
3	02:22	02:27	10	10
4	02:28	02:33	10	10
5	02:34	02:39	10	10
6	02:40	02:45	10	10
7	02:46	02:51	10	10
8	02:52	02:57	10	10
9	02:58	03:03	10	10
10	03:04	03:09	10	10
11	03:10	03:15	10	10
12	03:16	03:21	10	10
13	03:22	03:27	10	10
14	03:28	03:33	10	10
15	03:34	03:39	10	10

SUMMARY OF VISIBLE EMISSIONS

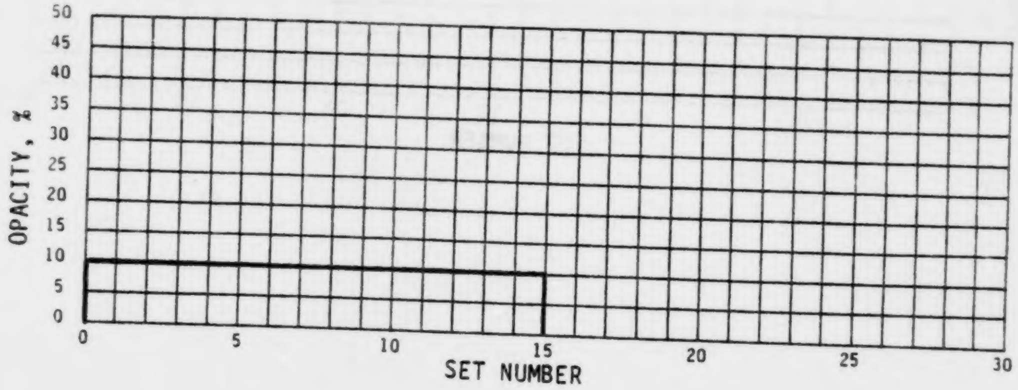


TABLE C-72. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	09/24/81
Type of plant	Rotary spin
Distance from observer to discharge point	600 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	100 ft
Direction of observer from discharge point	S
Description of background	Blue sky
Description of sky	60% clouds
Wind direction	NNE
Wind velocity	5-10 mph
Color of plume	Gray-green
Duration of observation	18 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:16 a.m.	09:21 a.m.	15	11
2	09:22	09:27	10	10
3	09:35	09:40	10	10

SUMMARY OF VISIBLE EMISSIONS

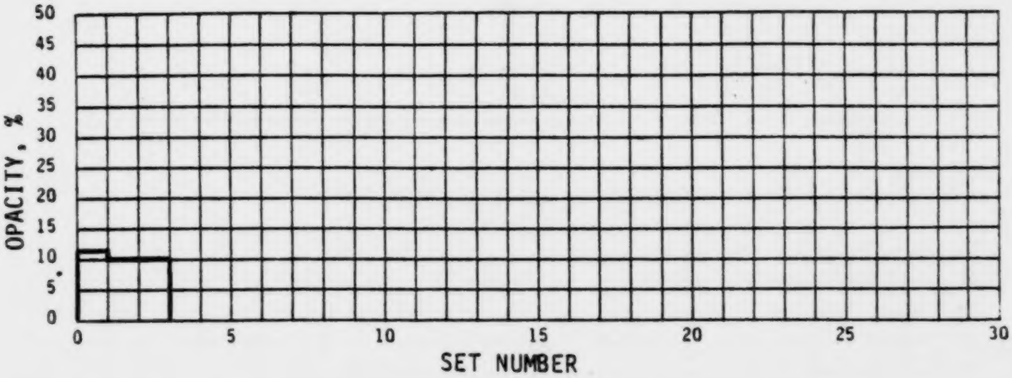


TABLE C-73. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	09/24/81
Type of plant	Rotary spin
Distance from observer to discharge point	600 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	100 ft
Direction of observer from discharge point	S
Description of background	Blue sky
Description of sky	40% clouds
Wind direction	NNE to SSW
Wind velocity	0-5 mph
Color of plume	Red-green-white
Duration of observation	114 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:06 p.m.	12:11 p.m.	10	10
2	12:12	12:17	15	11
3	12:18	12:23	10	8
4	12:24	12:29	15	7
5	12:30	12:35	15	10
6	12:36	12:41	15	11
7	12:42	12:47	15	12
8	12:49	12:54	15	10
9	12:55	01:00	15	10
10	01:01	01:06	10	8
11	01:07	01:12	10	8
12	01:13	01:18	10	8
13	01:19	01:24	10	7
14	01:25	01:30	10	7
15	01:31	01:36	10	9
16	01:37	01:42	10	9
17	01:48	01:53	10	6
18	01:54	01:59	10	7
19	02:00	02:05	10	8

SUMMARY OF VISIBLE EMISSIONS

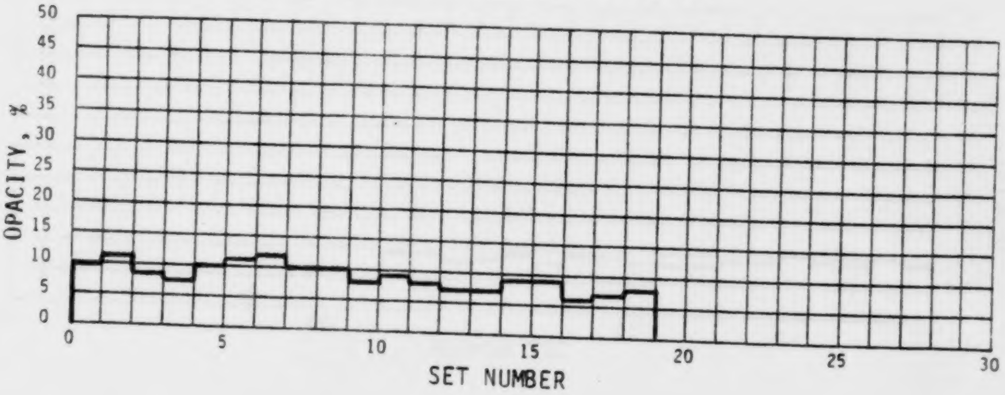


TABLE C-74. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	09/24/81
Type of plant	Rotary spin
Distance from observer to discharge point	200 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	100 ft
Direction of observer from discharge point	NW
Description of background	Blue sky
Description of sky	40% clouds
Wind direction	NW to SE
Wind velocity	0-5 mph
Color of plume	Green-white
Duration of observation	108 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:50 p.m.	03:55 p.m.	10	9
2	03:56	04:01	10	10
3	04:02	04:07	10	9
4	04:08	04:13	10	9
5	04:14	04:19	10	10
6	04:20	04:25	10	9
7	04:26	04:31	10	9
8	04:32	04:37	10	8
9	04:38	04:43	10	8
10	04:49	04:54	10	8
11	04:55	05:00	10	9
12	05:01	05:06	10	9
13	05:17	05:22	10	7
14	05:30	05:35	10	9
15	05:36	05:41	10	8
16	05:42	05:47	10	7
17	05:51	05:56	10	9
18	06:09	06:14	10	9

SUMMARY OF VISIBLE EMISSIONS

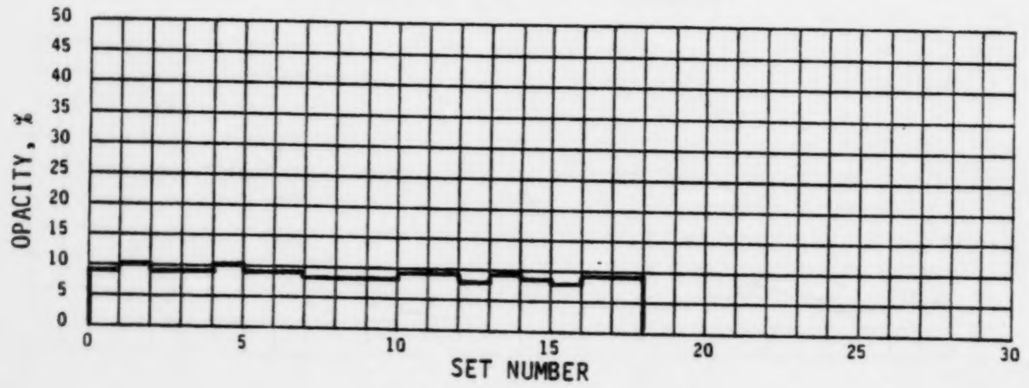


TABLE C-75. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	10/17/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	200 ft
Direction of observer from discharge point	SW
Description of background	Not reported
Description of sky	100% overcast
Wind direction	SW to NE
Wind velocity	Not reported
Color of plume	White
Duration of observation	72 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:30 a.m.	09:35 a.m.	25	17
2	09:42	09:47	30	24
3	09:54	09:59	25	25
4	10:06	10:11	30	29
5	10:18	10:23	25	24
6	10:30	10:35	35	29
7	11:20	11:25	30	26
8	11:32	11:37	30	25
9	11:44	11:49	30	25
10	11:56	12:01 p.m.	25	20
11	12:08 p.m.	12:13	30	25
12	12:20	12:25	20	16

SUMMARY OF VISIBLE EMISSIONS

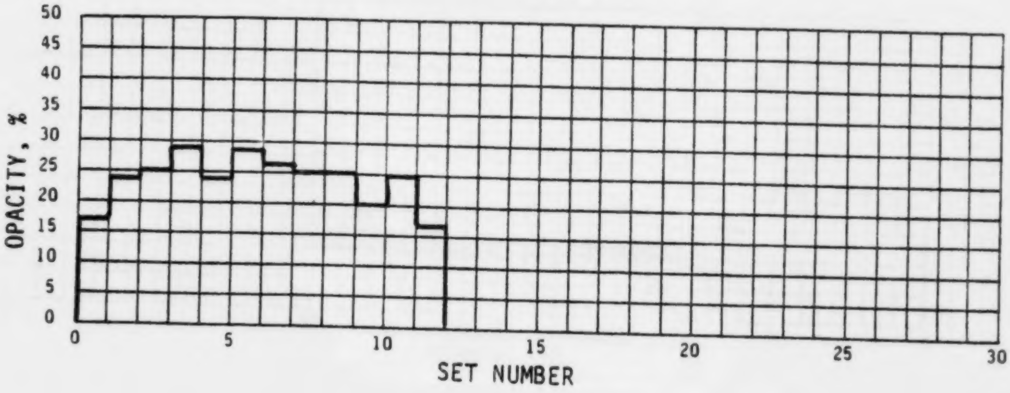


TABLE C-76. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	10/18/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	200 ft
Direction of observer from discharge point	SW
Description of background	Not reported
Description of sky	80%-100% clouds
Wind direction	NW to SE
Wind velocity	15-20 mph
Color of plume	White
Duration of observation	72 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	08:30 a.m.	08:35 a.m.	25	15
2	08:42	08:47	25	22
3	08:54	08:59	25	22
4	09:06	09:11	25	20
5	09:18	09:23	30	22
6	09:30	09:35	25	20
7	10:20	10:25	15	15
8	10:32	10:37	15	14
9	10:44	10:49	15	12
10	10:56	11:01	15	11
11	11:10	11:15	15	11
12	11:22	11:27	20	15

SUMMARY OF VISIBLE EMISSIONS

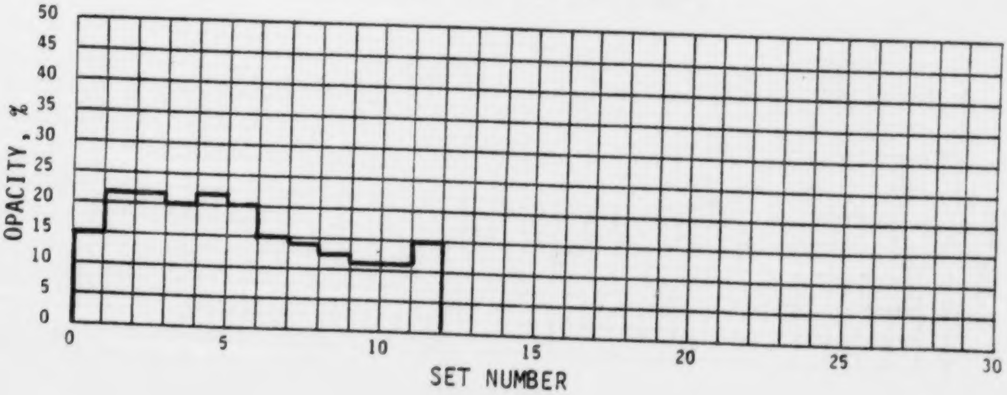


TABLE C-77. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	10/18/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	200 ft
Direction of observer from discharge point	SW
Description of background	Not reported
Description of sky	50%-100% clouds
Wind direction	NW to SE
Wind velocity	15-20 mph
Color of plume	White
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	02:22 p.m.	02:27 p.m.	20	17
2	02:40	02:45	20	14
3	03:06	03:11	20	15
4	03:18	02:23	20	15
5	04:26	04:31	15	11
6	04:38	04:43	15	11
7	04:50	04:55	15	12
8	05:02	05:07	15	11
9	05:16	05:21	25	15
10	05:28	05:33	15	12

SUMMARY OF VISIBLE EMISSIONS

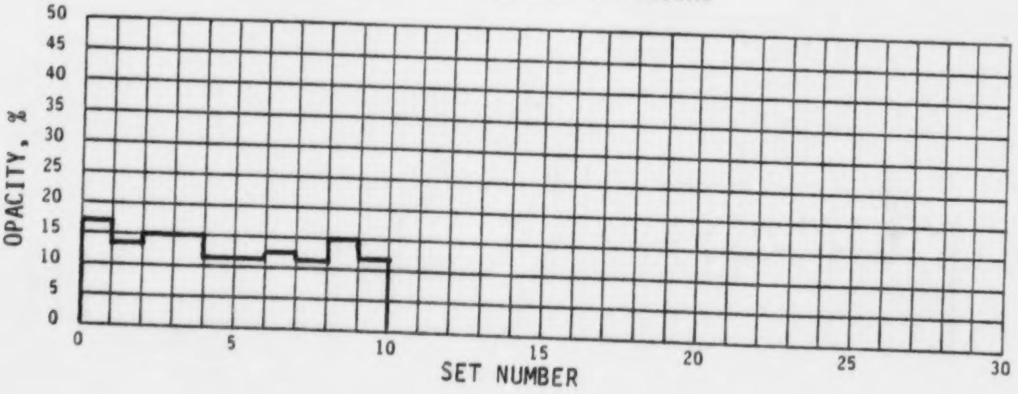


TABLE C-78. SUMMARY OF VISIBLE EMISSIONS--LINE A

Date	10/19/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Wet ESP outlet
Height of observation point	Ground level
Height of point of discharge	200 ft
Direction of observer from discharge point	SSW
Description of background	Not reported
Description of sky	Clear
Wind direction	NW to SE
Wind velocity	10 mph
Color of plume	White
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	09:48 a.m.	09:53 a.m.	20	19
2	10:00	10:05	25	21
3	10:12	10:17	20	14
4	10:24	10:29	15	15
5	10:36	10:41	15	12
6	10:48	10:53	15	15
7	11:50	11:55	20	13
8	12:01 p.m.	12:06 p.m.	15	11
9	12:25	12:30	25	16
10	12:37	12:42	25	15

SUMMARY OF VISIBLE EMISSIONS

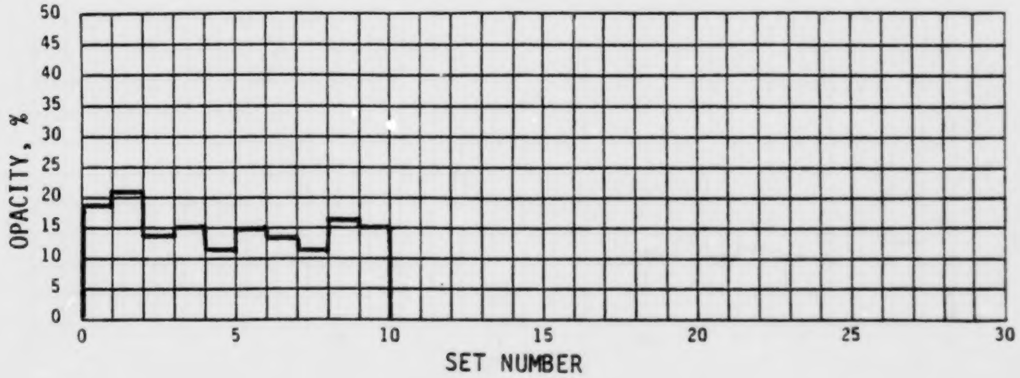


TABLE C-79. SUMMARY OF VISIBLE EMISSIONS--LINE B

Date	12/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	20 ft
Location of discharge	Rectangular mixing chamber stack
Height of observation point	15 ft
Height of point of discharge	30 ft
Direction of observer from discharge point	SE
Description of background	Not reported
Description of sky	80% clouds
Wind direction	NW
Wind velocity	7 mph
Color of plume	White
Duration of observation	96 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	12:33 p.m.	12:38 p.m.	5	5
2	12:39	12:44	5	5
3	12:45	12:50	5	5
4	12:51	12:56	5	5
5	12:47	01:02	5	5
6	01:03	01:08	5	5
7	01:09	01:14	5	5
8	01:15	01:20	5	5
9	01:21	01:26	5	5
10	01:27	01:32	5	5
11	01:33	01:38	5	5
12	03:46	03:51	5	5
13	04:25	04:30	5	5
14	04:35	04:40	5	5
15	04:41	04:56	5	5
16	04:47	04:52	5	5

SUMMARY OF VISIBLE EMISSIONS

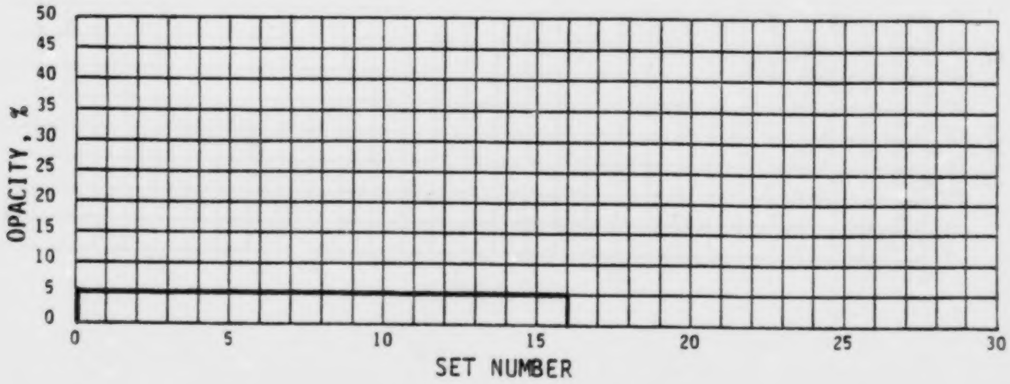


TABLE C-80. SUMMARY OF VISIBLE EMISSIONS--LINE B

Date	12/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	20 ft
Location of discharge	Rectangular mixing chamber stack
Height of observation point	15 ft
Height of point of discharge	30 ft
Direction of observer from discharge point	SE
Description of background	Not reported
Description of sky	90% clouds
Wind direction	NW
Wind velocity	7 mph
Color of plume	White
Duration of observation	78 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:20 a.m.	09:25 a.m.	5	5
2	09:37	09:42	5	5
3	10:01	10:06	5	5
4	10:08	10:13	5	5
5	10:19	10:24	5	5
6	10:24	10:29	5	5
7	12:30 p.m.	12:35 p.m.	5	5
8	12:44	12:49	5	5
9	12:50	12:55	5	5
10	12:56	01:01	5	5
11	01:03	01:08	5	5
12	01:09	01:14	5	5
13	01:15	01:20	5	5

SUMMARY OF VISIBLE EMISSIONS

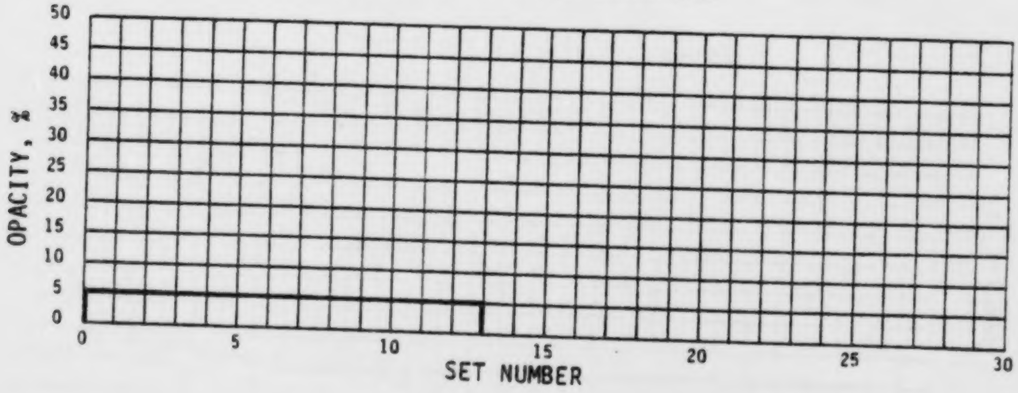


TABLE C-81. SUMMARY OF VISIBLE EMISSIONS--LINE B

Date	12/11/81
Type of plant	Rotary spin
Distance from observer to discharge point	20 ft
Location of discharge	Rectangular mixing chamber stack
Height of observation point	15 ft
Height of point of discharge	30 ft
Direction of observer from discharge point	SE
Description of background	Not reported
Description of sky	Overcast
Wind direction	NW
Wind velocity	7 mph
Color of plume	White
Duration of observation	132 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:14 a.m.	10:19 a.m.	5	5
2	10:20	10:25	5	5
3	10:26	10:31	5	5
4	10:32	10:37	5	5
5	10:38	10:43	5	5
6	10:44	10:49	5	5
7	10:55	11:00	5	5
8	11:01	11:06	5	5
9	11:07	11:12	5	5
10	11:13	11:18	5	5
11	01:20 p.m.	01:25 p.m.	5	5
12	01:26	01:31	5	5
13	01:32	01:37	5	5
14	01:38	01:43	5	5
15	01:44	01:49	5	5
16	01:50	01:55	5	5
17	01:56	02:01	5	5
18	02:02	02:07	5	5
19	02:08	02:13	5	5
20	02:14	02:19	5	5
21	02:20	02:25	5	5
22	02:26	02:31	5	5

SUMMARY OF VISIBLE EMISSIONS

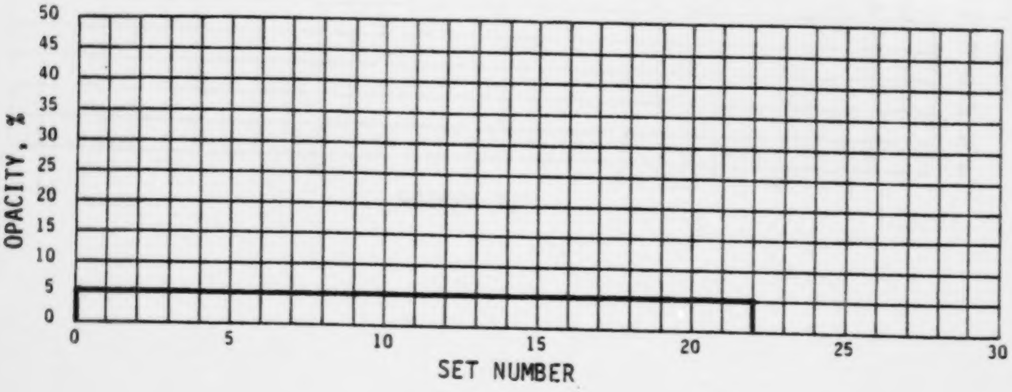


TABLE C-82. SUMMARY OF VISIBLE EMISSIONS--LINE E

Date	09/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Wet ESP outlet stack on forming, curing, cooling, and asphalt
Height of observation point	20 ft
Height of point of discharge	150 ft
Direction of observer from discharge point	SW
Description of background	Not reported
Description of sky	50% clouds
Wind direction	Westerly
Wind velocity	10-15 mph
Color of plume	White
Duration of observation	12 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:48 a.m.	11:53 a.m.	50	49
2	03:01 p.m.	03:06 p.m.	60	59

SUMMARY OF VISIBLE EMISSIONS

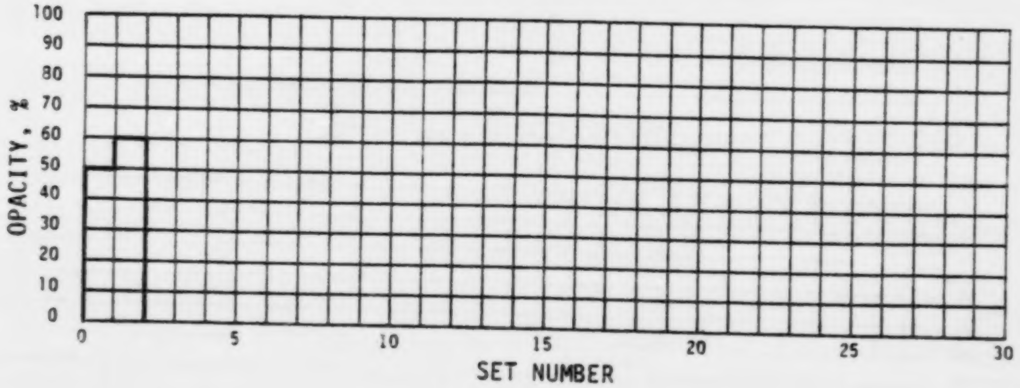


TABLE C-83. SUMMARY OF VISIBLE EMISSIONS--LINE E

Date	09/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Wet ESP outlet stack on forming, curing, cooling, and asphalt
Height of observation point	20 ft
Height of point of discharge	150 ft
Direction of observer from discharge point	SW
Description of background	Not reported
Description of sky	50% clouds
Wind direction	W
Wind velocity	5-15 mph
Color of plume	White
Duration of observation	66 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	04:50 p.m.	04:55 p.m.	65	61
2	04:46	05:01	60	60
3	05:02	05:07	58	60
4	05:08	05:13	50	50
5	05:14	05:19	50	46
6	05:20	05:25	60	53
7	06:35	06:40	60	56
8	06:41	06:46	70	68
9	06:47	06:52	70	70
10	06:53	06:58	70	70
11	06:59	07:04	70	69

SUMMARY OF VISIBLE EMISSIONS

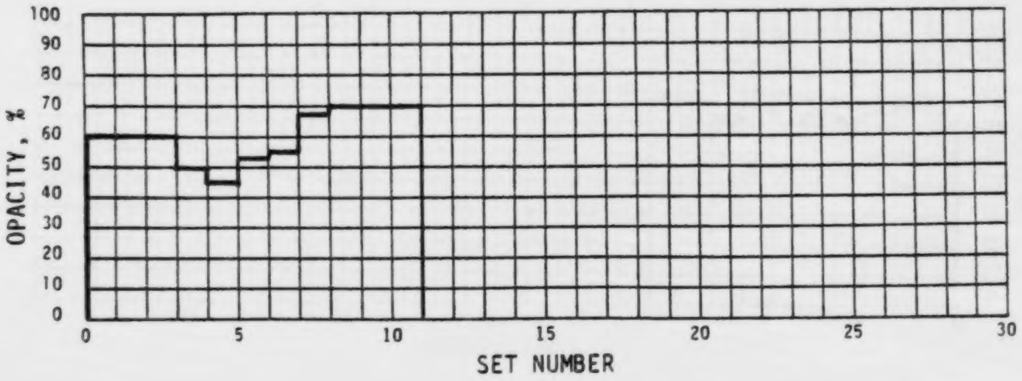


TABLE C-84. SUMMARY OF VISIBLE EMISSIONS--LINE E

Date	09/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	400 ft
Location of discharge	Wet ESP outlet stack on forming, curing, cooling, and asphalt
Height of observation point	Ground level
Height of point of discharge	150 ft
Direction of observer from discharge point	E
Description of background	Not reported
Description of sky	1% clouds
Wind direction	SW
Wind velocity	5-10 mph
Color of plume	White
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:57 a.m.	11:02 a.m.	65	60
2	11:03	11:08	70	67
3	11:09	11:14	65	65
4	11:15	11:20	65	62
5	11:21	11:26	65	63
6	12:10 p.m.	12:15 p.m.	65	60
7	12:16	12:21	70	66
8	12:22	12:27	65	62
9	12:28	12:33	70	67
10	12:34	12:39	75	68

SUMMARY OF VISIBLE EMISSIONS

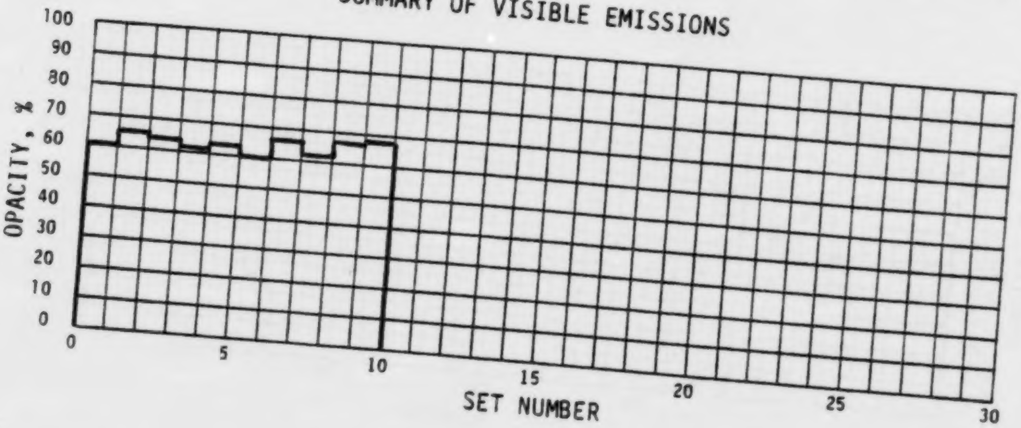


TABLE C-85. SUMMARY OF VISIBLE EMISSIONS--LINE E

Date	09/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Wet ESP outlet stack on forming, curing, cooling, and asphalt
Height of observation point	Ground level
Height of point of discharge	150 ft
Direction of observer from discharge point	SE
Description of background	Blue sky
Description of sky	Clear for sets 1-5; 90% overcast for 6&7
Wind direction	SW
Wind velocity	5-10 mph
Color of plume	White
Duration of observation	42 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	02:12 p.m.	02:17 p.m.	70	66
2	02:18	02:23	70	66
3	02:24	02:29	60	59
4	02:30	02:35	65	63
5	02:36	02:41	65	60
6	03:55	04:00	60	55
7	04:01	04:07	60	56

SUMMARY OF VISIBLE EMISSIONS

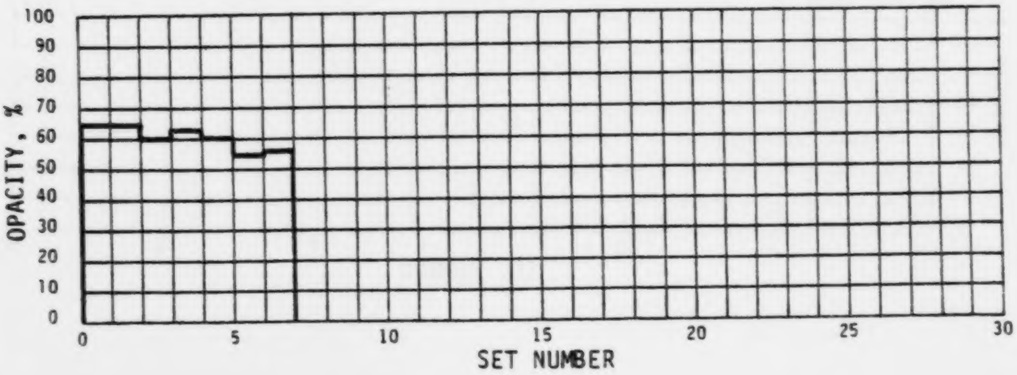


TABLE C-86. SUMMARY OF VISIBLE EMISSIONS--LINE E

Date	09/11/81
Type of plant	Rotary spin
Distance from observer to discharge point	450 ft
Location of discharge	Wet ESP outlet stack on forming, curing, cooling, and asphalt
Height of observation point	Ground level
Height of point of discharge	150 ft
Direction of observer from discharge point	S
Description of background	Not reported
Description of sky	40% clouds
Wind direction	WSW
Wind velocity	3-5 mph
Color of plume	White-blue
Duration of observation	24 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	04:30 p.m.	04:35 p.m.	85	81
2	04:40	04:45	85	78
3	04:50	04:55	85	79
4	05:00	05:05	85	77

SUMMARY OF VISIBLE EMISSIONS

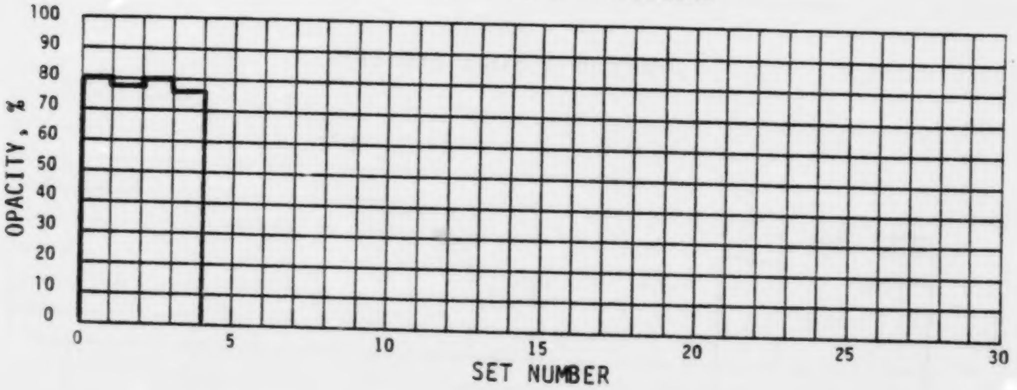


TABLE C-87. SUMMARY OF VISIBLE EMISSIONS--LINE E

Date	09/11/81
Type of plant	Rotary spin
Distance from observer to discharge point	300 ft
Location of discharge	Wet ESP outlet stack on forming, curing, cooling, and asphalt
Height of observation point	About 50 ft
Height of point of discharge	150 ft
Direction of observer from discharge point	SE
Description of background	Blue sky
Description of sky	Clear
Wind direction	W
Wind velocity	5-10 mph
Color of plume	Brownish white
Duration of observation	108 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:00 a.m.	10:05 a.m.	80	71
2	10:06	10:11	80	66
3	10:15	10:20	85	71
4	10:21	10:26	85	75
5	10:29	10:34	85	74
6	10:35	10:40	85	76
7	10:45	10:50	85	73
8	10:51	10:56	80	69
9	11:00	11:05	85	76
10	11:06	11:11	85	76
11	11:15	11:20	85	75
12	11:21	11:26	85	74
13	11:30	11:35	90	80
14	11:36	11:41	90	84
15	11:45	11:50	85	80
16	11:51	11:56	85	80
17	12:00 p.m.	12:05 p.m.	80	76
18	12:06	12:11	85	74

SUMMARY OF VISIBLE EMISSIONS

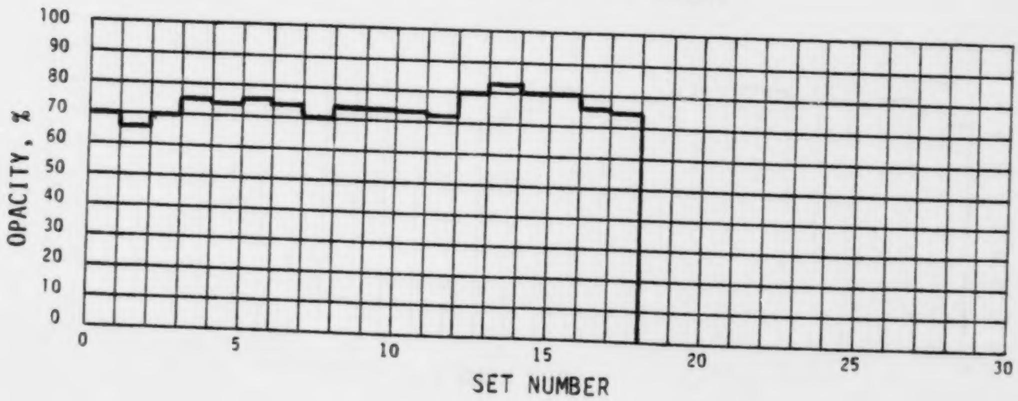


TABLE C-88. SUMMARY OF VISIBLE EMISSIONS--LINE E

Date	09/11/81
Type of plant	Rotary spin
Distance from observer to discharge point	1,000 ft
Location of discharge	Wet ESP outlet stack on forming, curing, cooling, and asphalt
Height of observation point	Ground level
Height of point of discharge	160 ft
Direction of observer from discharge point	S
Description of background	Blue sky
Description of sky	Clear
Wind direction	W
Wind velocity	5-10 mph
Color of plume	Brownish-white
Duration of observation	96 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	01:25 p.m.	01:30 p.m.	85	74
2	01:31	01:36	85	78
3	01:40	01:45	90	83
4	01:46	01:51	90	80
5	01:55	02:00	90	82
6	02:01	02:06	85	80
7	02:10	02:15	95	84
8	02:16	02:21	100	85
9	02:25	02:30	90	84
10	02:31	02:36	90	82
11	02:40	02:45	85	79
12	02:46	02:51	85	79
13	02:55	03:00	85	79
14	03:01	03:06	90	83
15	03:10	03:15	85	74
16	03:16	03:21	80	72

SUMMARY OF VISIBLE EMISSIONS

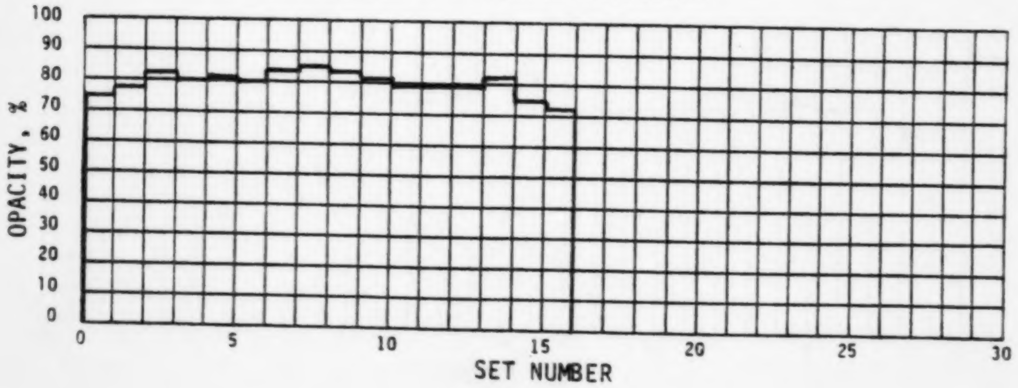


TABLE C-89. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	North forming stack
Height of observation point	10 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	E
Description of background	Green trees
Description of sky	50% clouds
Wind direction	NE to SW
Wind velocity	10 mph
Color of plume	Blue-gray
Duration of observation	126 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	05:15 p.m.	05:20 p.m.	10	10
2	05:21	05:26	10	10
3	05:27	05:32	10	10
4	05:33	05:38	10	10
5	05:39	05:44	10	10
6	05:45	05:50	10	10
7	05:51	05:56	10	10
8	05:57	06:02	10	10
9	06:03	06:08	10	10
10	06:09	06:14	10	10
11	06:15	06:20	10	10
12	06:21	06:26	10	10
13	06:27	06:32	10	10
14	06:33	06:38	10	10
15	06:50	06:55	10	10
16	06:56	07:01	10	10
17	07:02	07:07	10	10
18	07:08	07:13	10	10
19	07:14	07:19	10	10
20	07:20	07:25	10	10
21	07:26	07:31	10	10

SUMMARY OF VISIBLE EMISSIONS

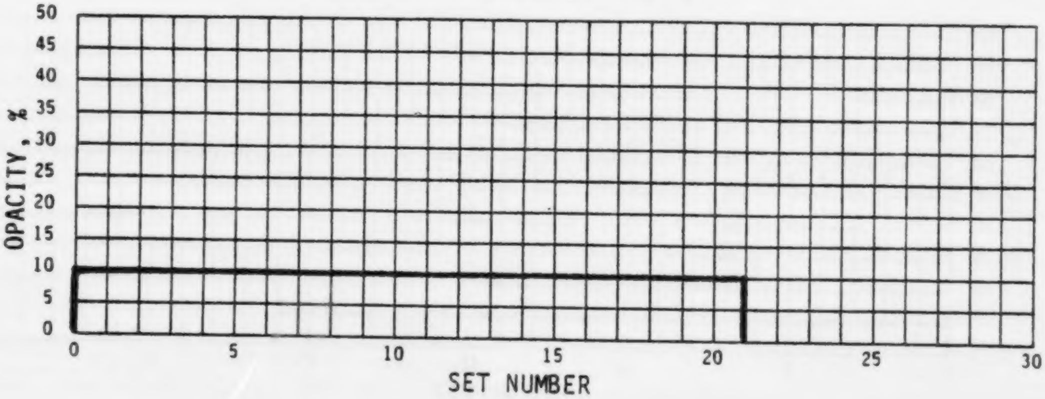


TABLE C-90. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	Middle forming stack
Height of observation point	10 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	E
Description of background	Green trees
Description of sky	50% clouds
Wind direction	NE to SW
Wind velocity	10 mph
Color of plume	Blue-gray
Duration of observation	126 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	05:15 p.m.	05:20 p.m.	5	5
2	05:21	05:26	5	5
3	05:27	05:32	5	5
4	05:33	05:38	5	5
5	05:39	05:44	5	5
6	05:45	05:50	5	5
7	05:51	05:56	5	5
8	05:57	06:02	5	5
9	06:03	06:08	5	5
10	06:09	06:14	5	5
11	06:15	06:20	5	5
12	06:21	06:26	5	5
13	06:27	06:32	5	5
14	06:33	06:38	5	5
15	06:50	06:55	5	5
16	06:56	07:01	5	5
17	07:02	07:07	5	5
18	07:08	07:13	5	5
19	07:14	07:19	5	5
20	07:20	07:25	5	5
21	07:26	07:31	5	5

SUMMARY OF VISIBLE EMISSIONS

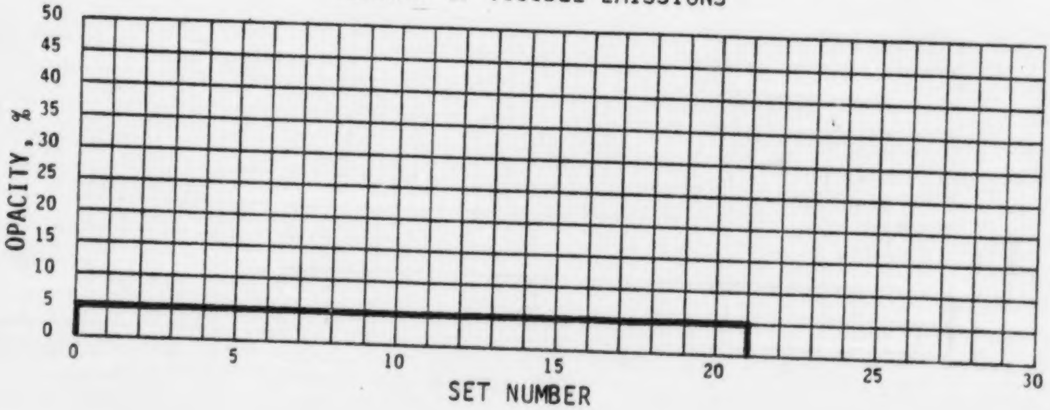


TABLE C-91. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	30 ft
Location of discharge	South forming stack
Height of observation point	6 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	W
Description of background	Not reported
Description of sky	Not reported
Wind direction	NE to SW
Wind velocity	5-10 mph
Color of plume	Blue-gray
Duration of observation	126 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	05:15 p.m.	05:20 p.m.	15	11
2	05:21	05:26	15	10
3	05:27	05:32	15	10
4	05:33	05:38	15	13
5	05:39	05:44	15	13
6	05:45	05:50	15	11
7	05:51	05:56	15	13
8	05:57	06:02	15	13
9	06:03	06:08	15	14
10	06:09	06:14	15	14
11	06:15	06:20	15	15
12	06:21	06:26	15	14
13	06:27	06:32	15	12
14	06:33	06:38	15	14
15	06:50	06:55	15	14
16	06:56	07:01	15	12
17	07:02	07:07	10	10
18	07:08	07:13	10	10
19	07:14	07:19	10	10
20	07:20	07:25	10	10
21	07:26	07:31	10	10

SUMMARY OF VISIBLE EMISSIONS

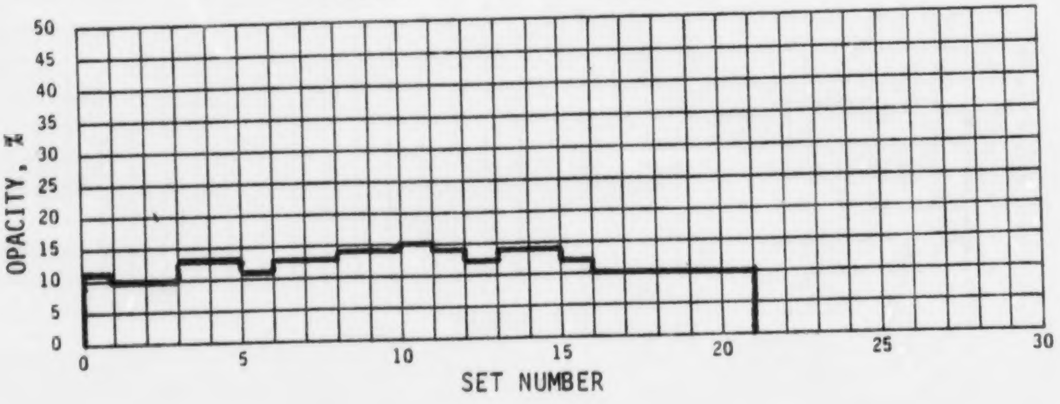


TABLE C-92. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	North curing/cooling stack
Height of observation point	10 ft
Height of point of discharge	10 ft above roof
Direction of observer from discharge point	E
Description of background	Green trees
Description of sky	50% clouds
Wind direction	NE to SW
Wind velocity	10 mph
Color of plume	Blue-gray
Duration of observation	84 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	05:28 p.m.	05:33 p.m.	30	26
2	05:45	05:50	30	27
3	05:51	05:56	30	29
4	06:00	06:05	30	27
5	06:06	06:11	30	27
6	06:18	06:23	30	27
7	06:24	06:29	30	26
8	06:30	06:35	30	25
9	06:36	06:41	30	25
10	06:42	06:47	30	25
11	06:48	06:53	30	24
12	07:01	07:06	25	24
13	07:13	07:18	30	25
14	07:22	07:27	30	25

SUMMARY OF VISIBLE EMISSIONS

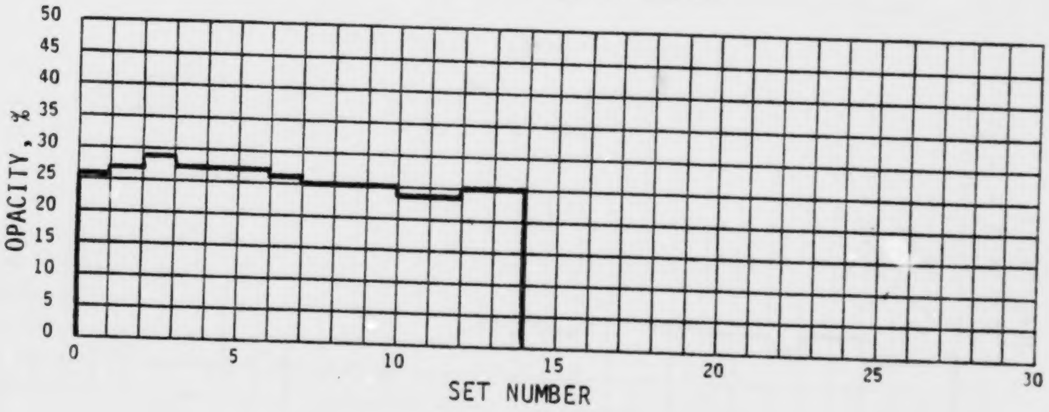


TABLE C-93. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/09/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	South curing stack
Height of observation point	10 ft
Height of point of discharge	10 ft above roof
Direction of observer from discharge point	E
Description of background	Green trees
Description of sky	50% clouds
Wind direction	NE to SW
Wind velocity	10 mph
Color of plume	Blue-gray
Duration of observation	84 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	05:28 p.m.	05:33 p.m.	30	28
2	05:45	05:50	30	29
3	05:51	05:56	30	29
4	06:00	06:05	30	29
5	06:06	06:11	30	29
6	06:18	06:23	30	29
7	06:24	06:29	30	27
8	06:30	06:35	30	27
9	06:36	06:41	30	25
10	06:42	06:47	30	25
11	06:48	06:53	30	26
12	07:01	07:06	30	25
13	07:13	07:18	25	25
14	07:22	07:27	30	25

SUMMARY OF VISIBLE EMISSIONS

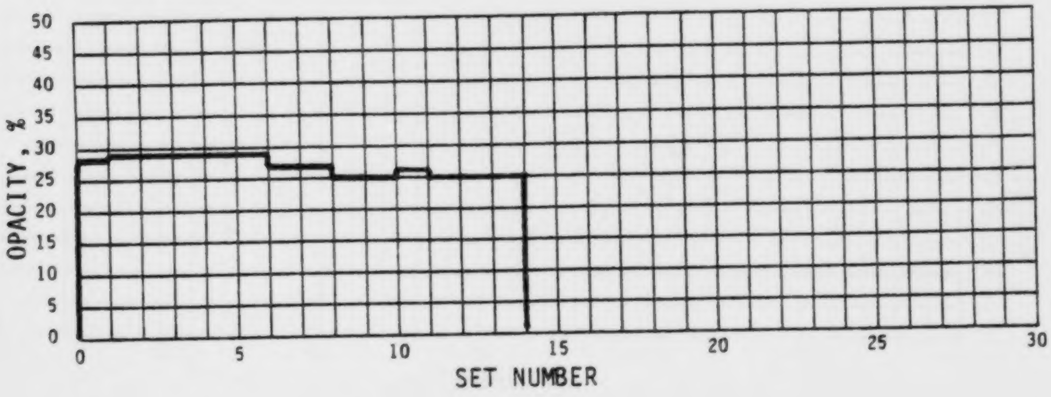


TABLE C-94. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	30 ft
Location of discharge	North forming stack
Height of observation point	10 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	E
Description of background	Green trees
Description of sky	50% clouds
Wind direction	W to E
Wind velocity	2-5 mph
Color of plume	Gray
Duration of observation	120 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:30 a.m.	09:35 a.m.	10	10
2	09:36	09:41	10	10
3	09:42	09:47	10	10
4	09:48	09:53	10	10
5	09:54	09:59	10	10
6	10:00	10:05	10	10
7	10:14	10:19	10	10
8	10:20	10:25	10	10
9	11:00	11:05	10	10
10	11:06	11:11	10	10
11	11:12	11:17	10	10
12	11:18	11:23	10	10
13	11:24	11:29	10	10
14	11:30	11:35	10	10
15	11:36	11:41	10	10
16	11:42	11:47	10	10
17	01:00 p.m.	01:05 p.m.	10	10
18	01:06	01:11	10	10
19	01:12	01:17	10	10
20	01:18	01:23	10	10

SUMMARY OF VISIBLE EMISSIONS

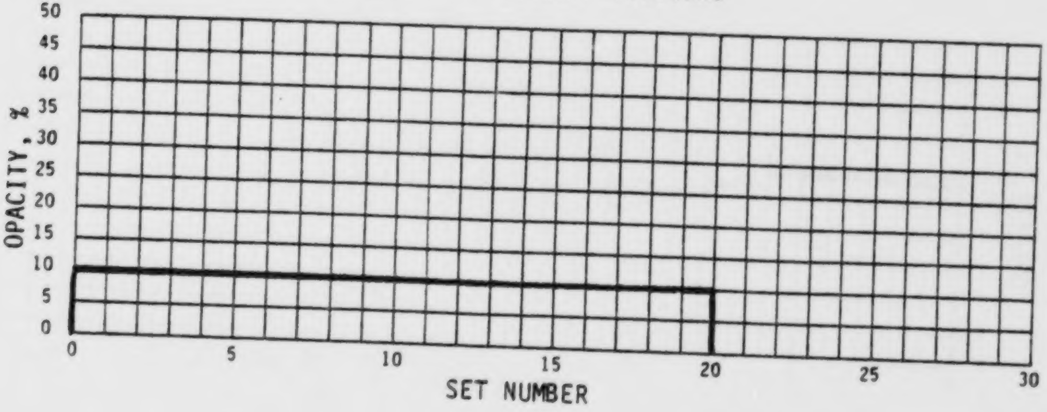


TABLE C-95. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	30 ft
Location of discharge	Middle forming stack
Height of observation point	10 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	E
Description of background	Green trees
Description of sky	50% clouds
Wind direction	W to E, N to S, NE to SE
Wind velocity	2-5 mph
Color of plume	Gray
Duration of observation	120 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:30 a.m.	09:35 a.m.	5	5
2	09:36	09:41	5	5
3	09:42	09:47	5	5
4	09:48	09:53	5	5
5	09:54	09:59	5	5
6	10:00	10:05	5	5
7	10:14	10:19	5	5
8	10:20	10:25	5	5
9	11:00	11:05	5	5
10	11:06	11:11	5	5
11	11:12	11:17	5	5
12	11:18	11:23	5	5
13	11:24	11:29	5	5
14	11:30	11:35	5	5
15	11:36	11:41	5	5
16	11:42	11:47	5	5
17	01:00 p.m.	01:05 p.m.	5	5
18	01:06	01:11	5	5
19	01:12	01:17	5	5
20	01:18	01:23	5	5

SUMMARY OF VISIBLE EMISSIONS

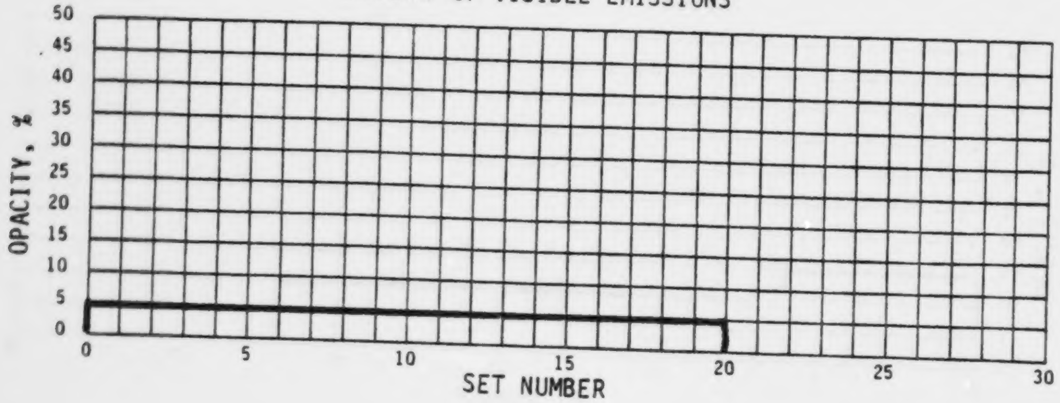


TABLE C-96. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/31
Type of plant	Rotary spin
Distance from observer to discharge point	60 ft
Location of discharge	South forming stack
Height of observation point	6 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	E
Description of background	Not reported
Description of sky	50%-60% clouds
Wind direction	N to S
Wind velocity	0-5 mph
Color of plume	Blue-gray
Duration of observation	132 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:30 a.m.	09:35 a.m.	15	15
2	09:36	09:41	15	15
3	09:42	09:47	15	15
4	09:48	09:53	15	15
5	09:54	09:59	15	15
6	10:00	10:05	15	15
7	10:14	10:19	15	11
8	10:20	10:25	10	10
9	10:26	10:31	15	10
10	10:58	11:03	10	10
11	11:04	11:09	10	10
12	11:10	11:15	10	10
13	11:16	11:21	10	10
14	11:22	11:27	10	10
15	11:28	11:33	15	10
16	11:34	11:39	15	10
17	11:40	11:45	10	10
18	11:46	11:51	10	10
19	01:00 p.m.	01:05 p.m.	10	10
20	01:06	01:11	10	10
21	01:12	01:17	10	10
22	01:18	01:23	10	10

SUMMARY OF VISIBLE EMISSIONS

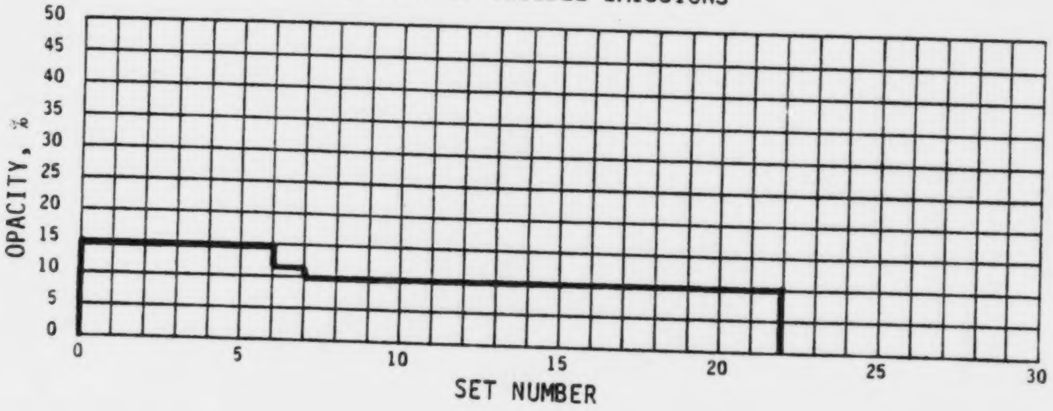


TABLE C-97. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	20 ft
Location of discharge	North forming stack
Height of observation point	12 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	30% clouds
Wind direction	W to E
Wind velocity	10 mph
Color of plume	Gray
Duration of observation	114 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:55 p.m.	04:00 p.m.	10	10
2	04:20	04:25	10	10
3	04:26	04:31	10	10
4	04:32	04:37	10	10
5	04:38	04:43	10	10
6	04:44	04:49	10	10
7	04:50	04:55	10	10
8	04:56	05:01	10	10
9	05:12	05:17	10	10
10	05:18	05:23	10	10
11	05:24	05:29	10	10
12	05:30	05:35	10	10
13	05:36	05:41	10	10
14	05:42	05:47	10	10
15	05:48	05:53	10	10
16	05:54	05:59	10	10
17	06:05	06:10	10	10
18	06:11	06:16	10	10
19	06:17	06:22	10	10

SUMMARY OF VISIBLE EMISSIONS

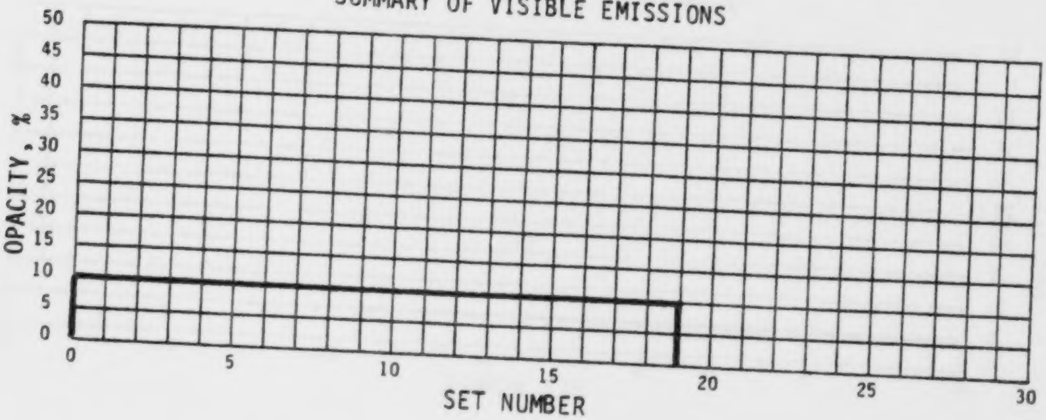


TABLE C-98. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	20 ft
Location of discharge	Middle forming stack
Height of observation point	12 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	30% clouds
Wind direction	W to E
Wind velocity	10 mph
Color of plume	Gray
Duration of observation	114 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:55 p.m.	04:00 p.m.	5	5
2	04:20	04:25	5	5
3	04:26	04:31	5	5
4	04:32	04:37	5	5
5	05:38	04:43	5	5
6	04:44	04:49	5	5
7	04:50	04:55	5	5
8	04:56	05:01	5	5
9	05:12	05:17	5	5
10	05:18	05:23	5	5
11	05:24	05:29	5	5
12	05:30	05:35	5	5
13	05:36	05:41	5	5
14	05:42	05:47	5	5
15	05:48	05:53	5	5
16	05:54	05:59	5	5
17	06:05	06:10	5	5
18	06:11	06:16	5	5
19	06:17	06:22	5	5

SUMMARY OF VISIBLE EMISSIONS

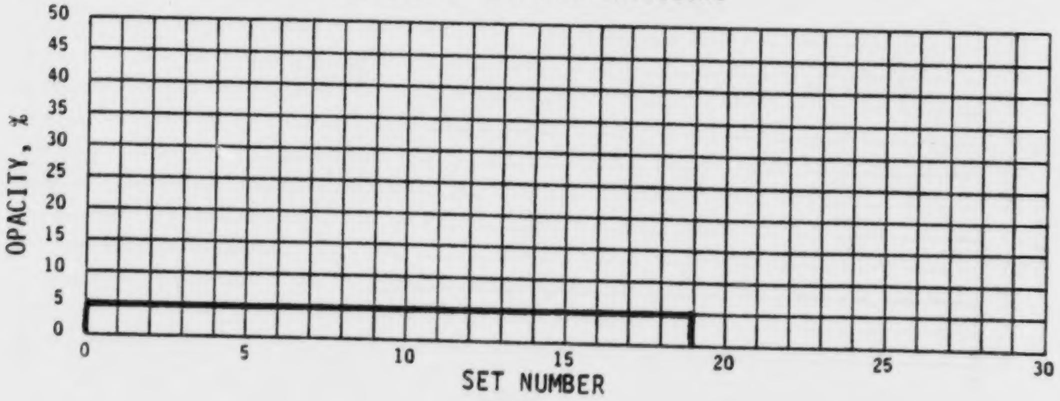


TABLE C-99. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	30 ft
Location of discharge	South forming stack
Height of observation point	6 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	W
Description of background	Not reported
Description of sky	50% clouds
Wind direction	N to S
Wind velocity	5-10 mph
Color of plume	Blue-gray
Duration of observation	114 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:56 p.m.	04:01 p.m.	10	10
2	04:27	04:32	10	10
3	04:33	04:38	10	10
4	04:39	04:44	10	10
5	04:45	04:50	10	10
6	04:51	04:56	10	10
7	04:57	05:02	10	10
8	05:15	05:20	15	11
9	05:21	05:26	10	10
10	05:27	05:32	10	10
11	05:33	05:38	10	6
12	05:39	05:44	10	10
13	05:45	05:50	10	10
14	05:54	05:59	10	10
15	06:01	06:05	10	10
16	06:07	06:12	10	10
17	06:13	06:18	10	10
18	06:19	06:24	10	8
19	06:25	06:30	10	6

SUMMARY OF VISIBLE EMISSIONS

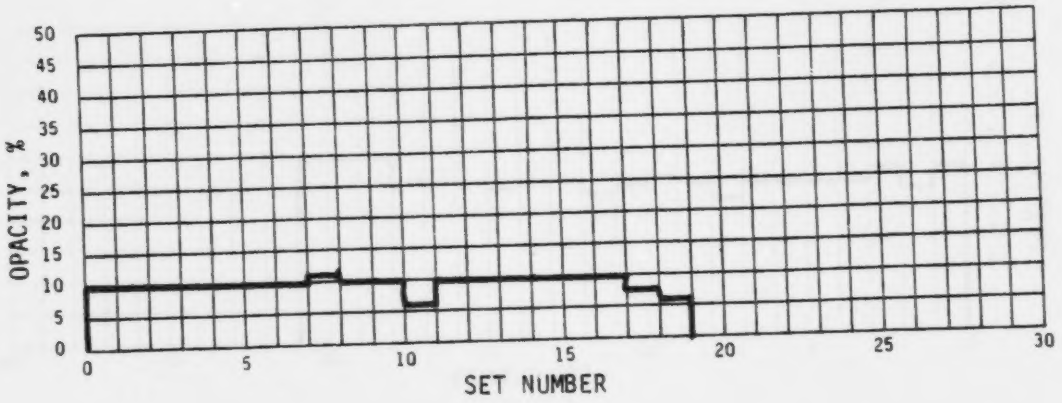


TABLE C-100. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	110 ft
Location of discharge	North curing/cooling stack
Height of observation point	10 ft above stack
Height of point of discharge	10 ft above roof
Direction of observer from discharge point	NE
Description of background	Green trees
Description of sky	20% clouds
Wind direction	N to S
Wind velocity	Not reported
Color of plume	Blue-white
Duration of observation	126 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6-min	6-min average
1	09:30 a.m.	09:35	35	30
2	09:36	09:41	35	30
3	09:42	09:47	35	30
4	09:48	09:53	35	30
5	10:02	10:07	30	30
6	10:16	10:21	35	31
7	10:22	10:27	35	30
8	10:28	10:33	30	28
9	10:58	11:03	35	30
10	11:04	11:09	30	29
11	11:10	11:15	35	31
12	11:18	11:23	35	30
13	11:24	11:29	30	28
14	11:31	11:36	30	29
15	11:37	11:42	35	27
16	11:43	11:48	30	28
17	01:00 p.m.	01:05 p.m.	35	34
18	01:06	01:11	35	31
19	01:12	01:17	35	31
20	01:18	01:23	35	33
21	01:24	01:29	35	32

SUMMARY OF VISIBLE EMISSIONS

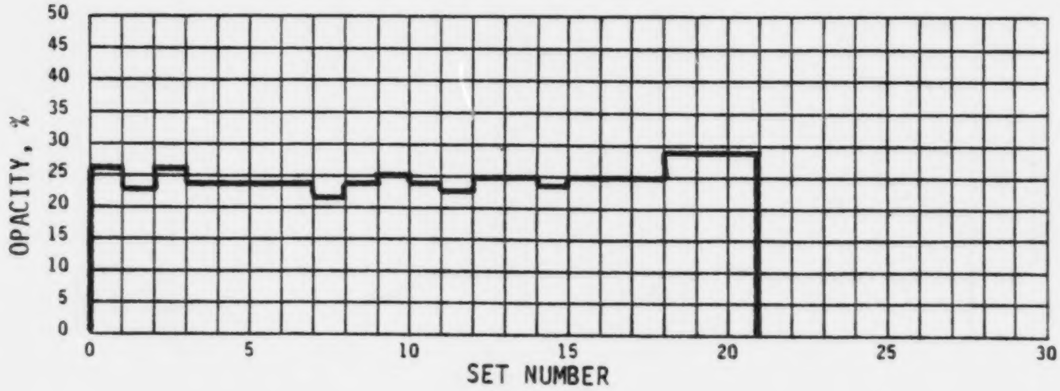


TABLE C-101. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	30 ft
Location of discharge	North curing/cooling stack
Height of observation point	Stack level
Height of point of discharge	10 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees and black background
Description of sky	15% clouds
Wind direction	W to E
Wind velocity	10 mph
Color of plume	Blue-white
Duration of observation	120 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:55 p.m.	04:00 p.m.	25	25
2	04:19	04:24	25	25
3	04:25	04:30	25	24
4	04:34	04:39	25	24
5	04:40	04:45	25	22
6	04:46	04:51	25	22
7	04:52	04:57	25	23
8	04:58	05:03	25	23
9	05:12	05:17	25	23
10	05:18	05:23	25	23
11	05:24	05:29	25	22
12	05:30	05:35	25	23
13	05:36	05:41	25	23
14	05:42	05:47	25	25
15	05:48	05:53	25	25
16	05:54	05:59	25	24
17	06:00	06:05	25	22
18	06:06	06:11	25	24
19	06:12	06:17	25	24
20	06:18	06:23	25	23

SUMMARY OF VISIBLE EMISSIONS

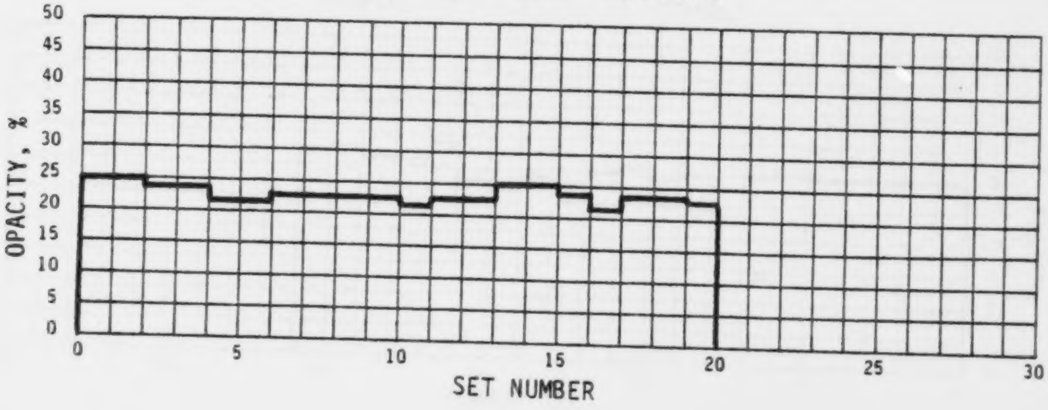


TABLE C-102. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	150 ft
Location of discharge	South curing stack
Height of observation point	10 ft above stack
Height of point of discharge	10 ft above roof
Direction of observer from discharge point	NE
Description of background	Green trees
Description of sky	20% clouds
Wind direction	N to S
Wind velocity	Not reported
Color of plume	Blue-white
Duration of observation	126 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:30 a.m.	09:35 a.m.	30	26
2	09:36	09:41	25	23
3	09:42	09:47	30	26
4	09:48	09:53	30	24
5	10:02	10:07	25	24
6	10:16	10:21	25	24
7	10:22	10:27	25	24
8	10:28	10:33	25	22
9	10:58	11:03	25	24
10	11:04	11:09	25	25
11	11:10	11:15	25	24
12	11:19	11:24	25	23
13	11:25	11:30	25	25
14	11:31	11:36	25	25
15	11:37	11:42	25	24
16	11:43	11:48	25	25
17	01:00 p.m.	01:05 p.m.	30	25
18	01:06	01:11	30	25
19	01:12	01:17	30	29
20	01:18	01:23	35	29
21	01:24	01:29	30	29

SUMMARY OF VISIBLE EMISSIONS

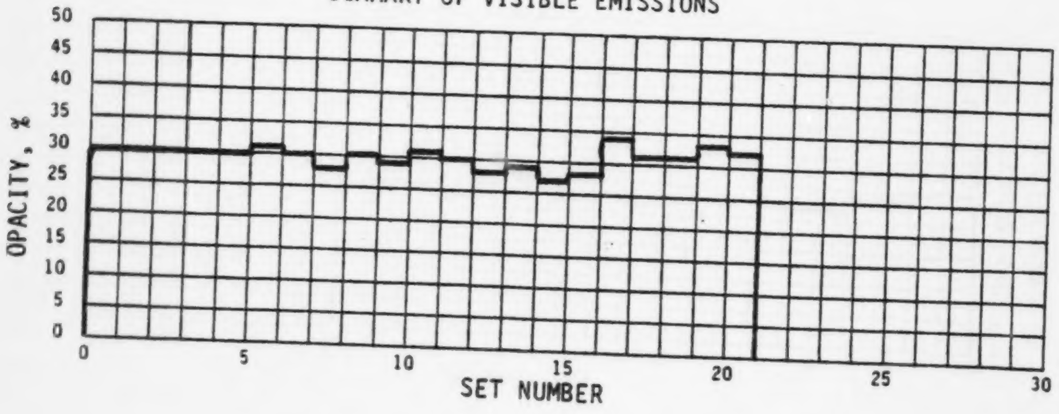


TABLE C-103. SUMMARY OF VISIBLE EMISSIONS--LINE F

Date	07/10/81
Type of plant	Rotary spin
Distance from observer to discharge point	40 ft
Location of discharge	South curing stack
Height of observation point	Stack level
Height of point of discharge	10 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees and black background
Description of sky	15% clouds
Wind direction	W to E
Wind velocity	10 mph
Color of plume	Blue-white
Duration of observation	120 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:55 p.m.	04:00 p.m.	30	26
2	04:19	04:24	35	30
3	04:25	04:30	35	28
4	04:34	04:39	35	28
5	04:40	04:45	30	26
6	04:46	04:51	35	26
7	04:52	04:57	30	27
8	04:58	05:03	35	27
9	05:12	05:17	30	26
10	05:18	05:23	30	25
11	05:24	05:29	30	25
12	05:30	05:35	25	25
13	05:36	05:41	25	25
14	05:42	05:47	30	25
15	05:48	05:53	30	26
16	05:54	05:59	30	27
17	06:00	06:05	30	25
18	06:06	06:11	30	25
19	06:12	06:17	30	26
20	06:18	06:23	30	27

SUMMARY OF VISIBLE EMISSIONS

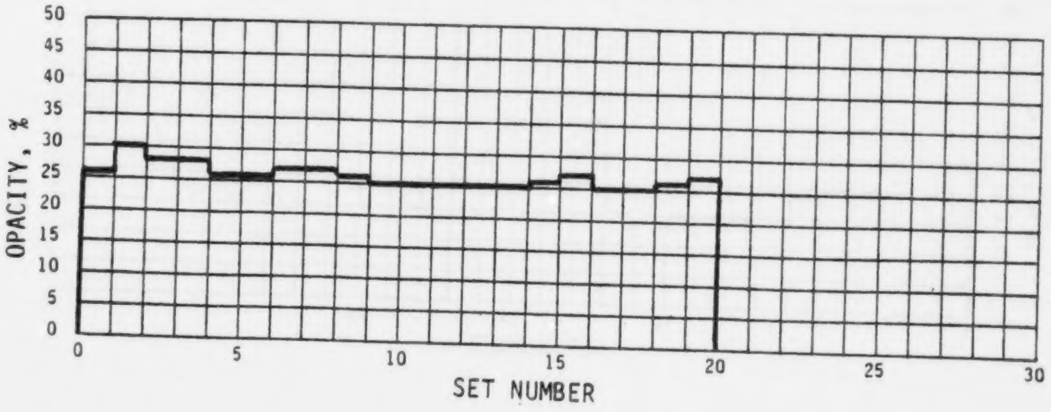


TABLE C-104. SUMMARY OF VISIBLE EMISSIONS--LINE G

Date	05/28/81
Type of plant	Rotary spin
Distance from observer to discharge point	250 ft
Location of discharge	Forming stack
Height of observation point	100 ft
Height of point of discharge	150 ft
Direction of observer from discharge point	E
Description of background	Not reported
Description of sky	50% clouds
Wind direction	N to S
Wind velocity	15 mph
Color of plume	White
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:05 p.m.	12:10 p.m.	25	25
2	12:11	12:16	25	20
3	12:17	12:22	20	20
4	12:23	12:28	20	20
5	12:29	12:34	20	20
6	12:35	12:40	20	19
7	12:41	12:46	15	15
8	12:47	12:52	15	15
9	12:53	12:58	15	15
10	12:59	01:04	15	15

SUMMARY OF VISIBLE EMISSIONS

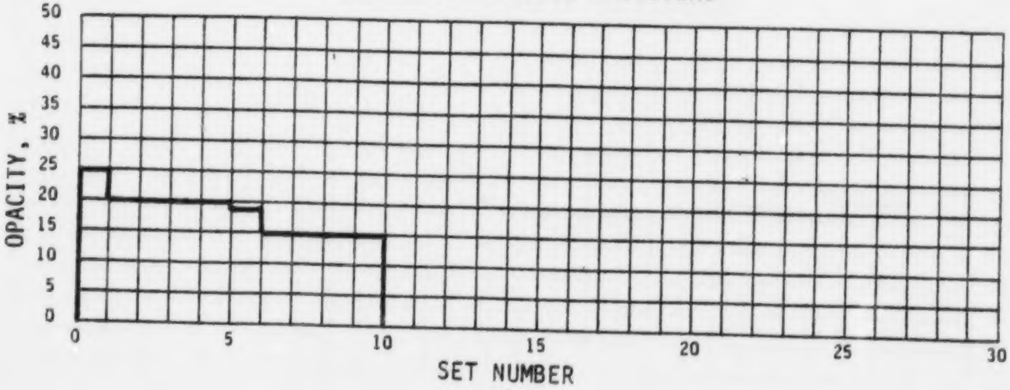


TABLE C-105. SUMMARY OF VISIBLE EMISSIONS--LINE G

Date	05/28/81
Type of plant	Rotary spin
Distance from observer to discharge point	350 ft
Location of discharge	Forming stack
Height of observation point	Ground level
Height of point of discharge	150 ft
Direction of observer from discharge point	W
Description of background	Not reported
Description of sky	Clear
Wind direction	N to S
Wind velocity	5 mph
Color of plume	White
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	04:12 p.m.	04:17 p.m.	20	20
2	04:18	04:23	20	20
3	04:24	04:29	20	20
4	04:30	04:35	20	20
5	04:36	04:41	20	20
6	04:42	04:47	20	20
7	04:48	04:53	20	20
8	04:54	04:59	20	20
9	05:00	05:05	20	20
10	05:06	05:11	20	20

SUMMARY OF VISIBLE EMISSIONS

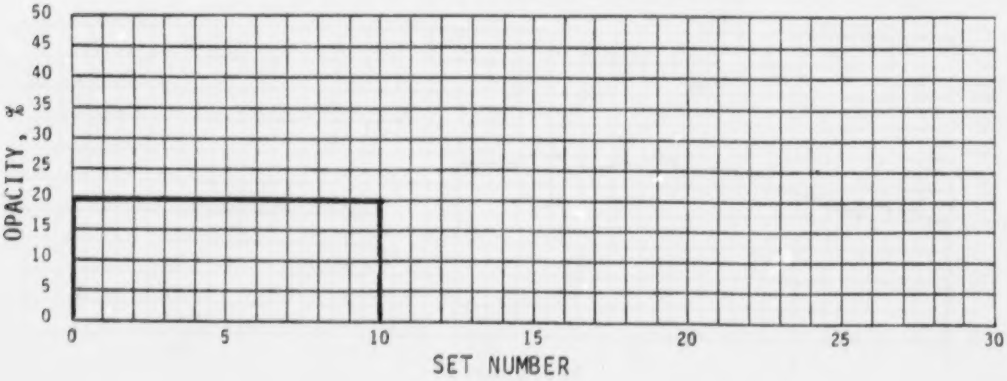


TABLE C-106. SUMMARY OF VISIBLE EMISSIONS--LINE G

Date	05/29/81
Type of plant	Rotary spin
Distance from observer to discharge point	500 ft
Location of discharge	Forming stack
Height of observation point	Ground level
Height of point of discharge	150 ft
Direction of observer from discharge point	SE
Description of background	Clear sky
Description of sky	Clear
Wind direction	S
Wind velocity	5 mph
Color of plume	Brown
Duration of observation	96 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	07:15 a.m.	07:20 a.m.	25	20
2	07:21	07:26	25	22
3	07:30	07:35	25	23
4	07:36	07:41	25	22
5	07:45	07:50	30	24
6	07:51	07:56	30	25
7	08:00	08:05	30	27
8	08:06	08:11	30	28
9	08:15	08:20	35	28
10	08:21	08:26	35	30
11	08:30	08:35	35	29
12	08:36	08:41	30	28
13	08:45	08:50	35	30
14	08:51	08:56	35	30
15	09:00	09:05	30	29
16	09:12	09:17	35	29

SUMMARY OF VISIBLE EMISSIONS

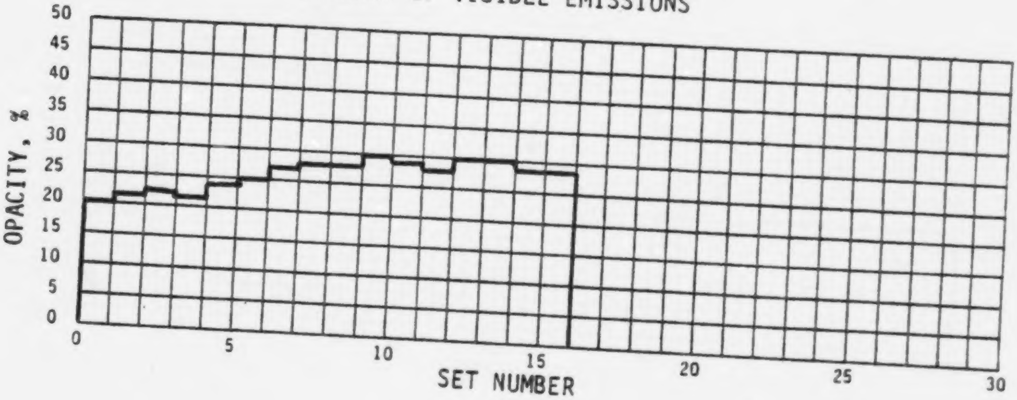


TABLE C-107. SUMMARY OF VISIBLE EMISSIONS--LINE H

Date	05/28/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	Curing stack
Height of observation point	15 ft
Height of point of discharge	Not available
Direction of observer from discharge point	NE
Description of background	Black rooftop
Description of sky	Clear to 80% clouds
Wind direction	N to W
Wind velocity	25 mph
Color of plume	Light blue
Duration of observation	72 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:01 a.m.	10:06 a.m.	10	2
2	10:13	10:18	10	5
3	10:26	10:32	10	4
4	10:39	10:44	10	2
5	10:52	10:57	10	6
6	11:05	11:10	10	3
7	11:18	11:23	10	5
8	11:31	11:36	5	3
9	12:17	12:22	10	3
10	12:29	12:34	10	3
11	12:41	12:46	10	4
12	12:52	12:57	10	3

SUMMARY OF VISIBLE EMISSIONS

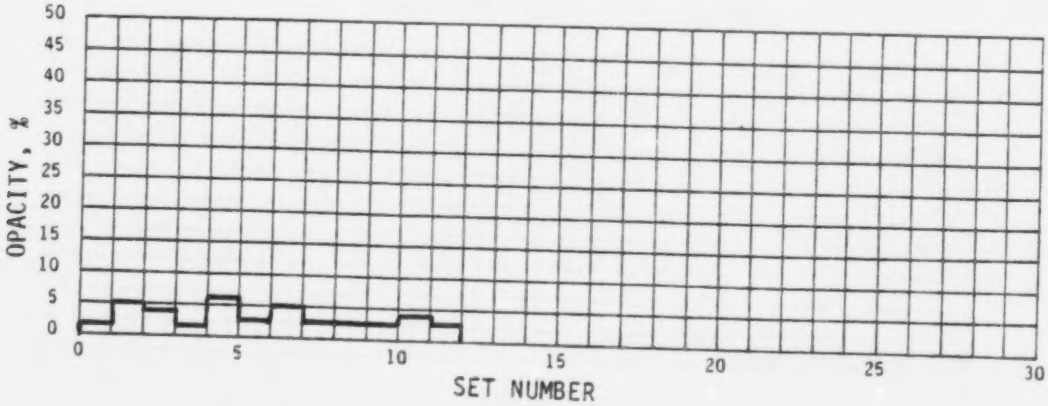


TABLE C-108. SUMMARY OF VISIBLE EMISSIONS--LINE H

Date	05/28/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	Curing stack
Height of observation point	Ground level
Height of point of discharge	Not available
Direction of observer from discharge point	W
Description of background	Black rooftop
Description of sky	Clear
Wind direction	N to W
Wind velocity	25 mph
Color of plume	Bluish
Duration of observation	84 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:12 p.m.	03:17 p.m.	10	3
2	03:24	03:29	5	3
3	03:36	03:41	5	1
4	03:48	03:53	5	0
5	04:00	04:05	5	2
6	04:12	04:17	5	3
7	04:24	04:29	5	1
8	04:36	04:41	5	3
9	04:48	04:53	10	4
10	05:00	05:05	10	3
11	05:12	05:17	10	5
12	05:24	05:29	10	4
13	05:36	05:41	10	3
14	05:48	05:53	10	5

SUMMARY OF VISIBLE EMISSIONS

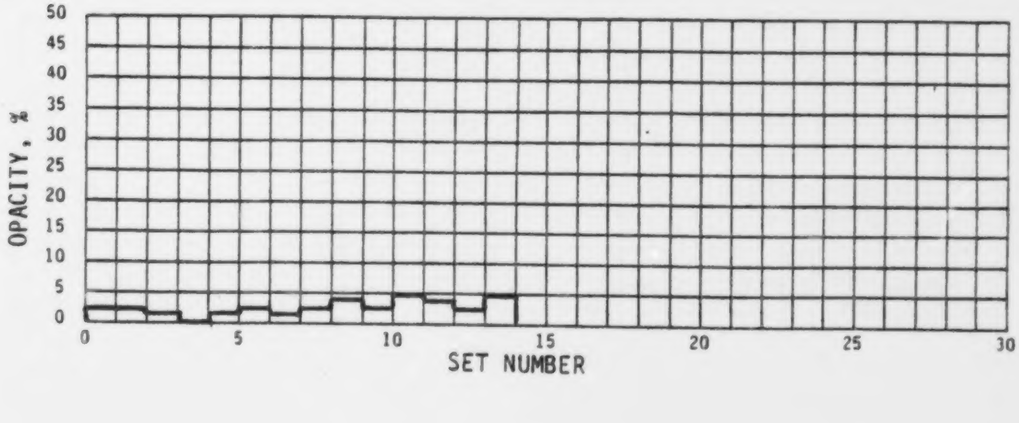


TABLE C-109. SUMMARY OF VISIBLE EMISSIONS--LINE H

Date	06/01/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	Curing stack
Height of observation point	Roof level
Height of point of discharge	20 ft
Direction of observer from discharge point	E
Description of background	Cloudy
Description of sky	100% overcast
Wind direction	S
Wind velocity	10 mph
Color of plume	Bluish
Duration of observation	114 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:24 a.m.	09:29 a.m.	0	0
2	09:30	09:35	10	2
3	09:36	09:41	5	0
4	09:42	09:47	0	0
5	09:54	09:59	0	0
6	10:00	10:05	15	4
7	10:06	10:11	0	0
8	10:12	10:17	0	0
9	10:24	10:29	10	5
10	11:30	11:35	0	0
11	11:36	11:41	0	0
12	11:42	11:47	0	0
13	11:54	11:59	0	0
14	12:00 p.m.	12:05 p.m.	5	1
15	12:06	12:11	5	1
16	12:12	12:17	0	0
17	12:24	12:29	5	0
18	12:30	12:35	5	0
19	12:36	12:41	0	0

SUMMARY OF VISIBLE EMISSIONS

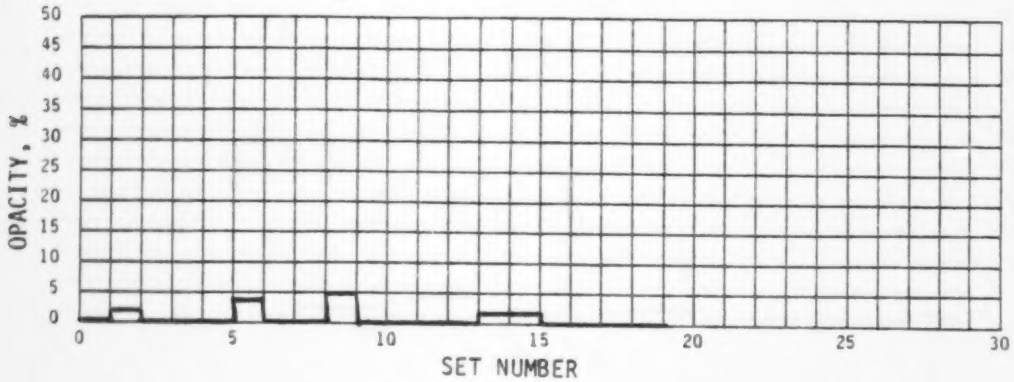


TABLE C-110. SUMMARY OF VISIBLE EMISSIONS--LINE H

Date	06/01/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	Curing stack
Height of observation point	Roof level
Height of point of discharge	20 ft
Direction of observer from discharge point	SSE
Description of background	Cloudy
Description of sky	Overcast
Wind direction	S
Wind velocity	10-15 mph
Color of plume	Bluish
Duration of observation	132 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	01:30 p.m.	01:35 p.m.	0	0
2	01:36	01:41	5	1
3	01:42	01:47	5	0
4	01:48	01:53	0	0
5	02:00	02:05	0	0
6	02:06	02:11	0	0
7	02:12	02:17	0	0
8	02:18	02:23	0	0
9	02:30	02:35	0	0
10	02:36	02:41	5	1
11	02:42	02:47	10	1
12	03:00	03:05	0	0
13	03:06	03:11	0	0
14	03:12	03:17	0	0
15	03:18	03:23	5	1
16	03:24	03:29	5	0
17	03:36	03:41	10	3
18	03:42	03:47	10	3
19	03:48	03:53	5	2
20	03:54	03:59	5	1
21	04:06	04:11	5	1
22	04:12	04:17	5	1

SUMMARY OF VISIBLE EMISSIONS

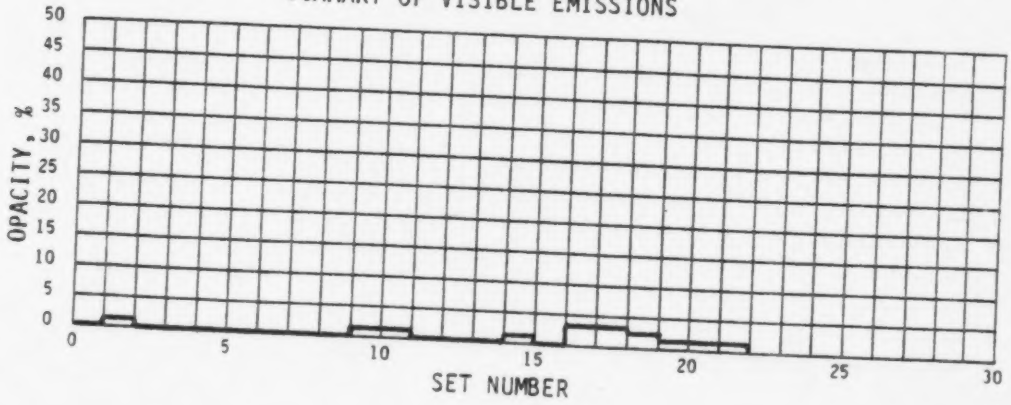


TABLE C-111. SUMMARY OF VISIBLE EMISSIONS--LINE H

Date	06/01/81
Type of plant	Rotary spin
Distance from observer to discharge point	50 ft
Location of discharge	Curing stack
Height of observation point	Roof level
Height of point of discharge	50 ft
Direction of observer from discharge point	SW
Description of background	Cloudy
Description of sky	Overcast
Wind direction	S
Wind velocity	10-15 mph
Color of plume	Bluish
Duration of observation	102 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	05:00 p.m.	05:05 p.m.	5	1
2	05:06	05:11	0	0
3	05:12	05:17	0	0
4	05:24	05:29	15	5
5	05:30	05:35	10	3
6	05:36	05:41	10	3
7	05:48	05:53	5	2
8	05:54	05:59	10	2
9	06:00	06:05	5	2
10	06:30	06:35	5	0
11	06:36	06:41	5	1
12	06:42	06:47	5	3
13	06:54	06:59	5	2
14	07:00	07:05	5	1
15	07:06	07:11	5	0
16	07:18	07:23	10	4
17	07:24	07:29	5	2

SUMMARY OF VISIBLE EMISSIONS

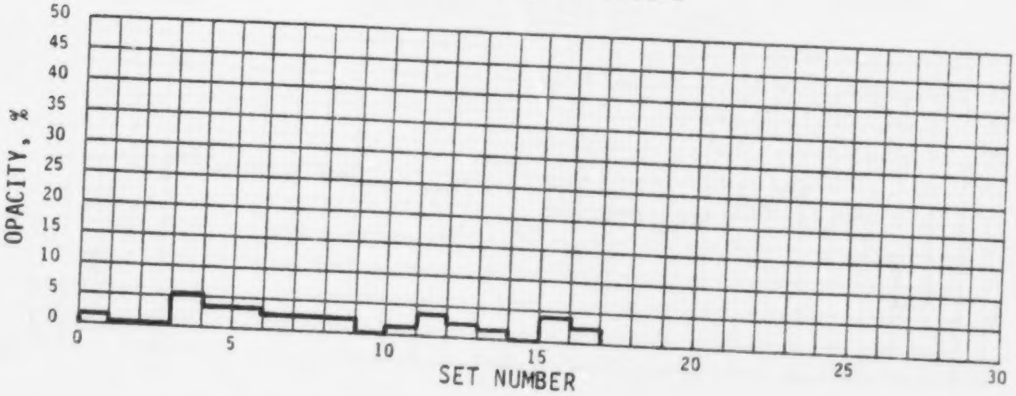


TABLE C-112. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/07/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	East forming stack
Height of observation point	90 ft
Height of point of discharge	15 ft above roof
Direction of observer from discharge point	SSW
Description of background	Trees
Description of sky	50% clouds
Wind direction	W to E
Wind velocity	25 mph
Color of plume	Blue-white
Duration of observation	150 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:11 a.m.	11:16 a.m.	30	27
2	11:17	11:22	30	12
3	11:23	11:28	30	19
4	11:29	11:34	30	26
5	11:35	11:40	35	24
6	11:41	11:46	35	30
7	11:47	11:52	40	27
8	11:53	11:58	40	30
9	11:59	12:04 p.m.	30	24
10	12:08 p.m.	12:13	40	22
11	12:14	12:19	30	25
12	12:22	12:27	40	24
13	12:28	12:33	40	28
14	12:52	12:57	35	22
15	01:01	01:06	35	32
16	01:09	01:14	40	29
17	01:15	01:20	30	27
18	01:25	01:30	30	25
19	01:31	01:36	35	28
20	01:37	01:42	40	29
21	01:43	01:48	35	30
22	02:08	02:13	35	28
23	02:14	02:19	35	29
24	02:21	02:26	40	29
25	02:29	02:34	35	31

SUMMARY OF VISIBLE EMISSIONS

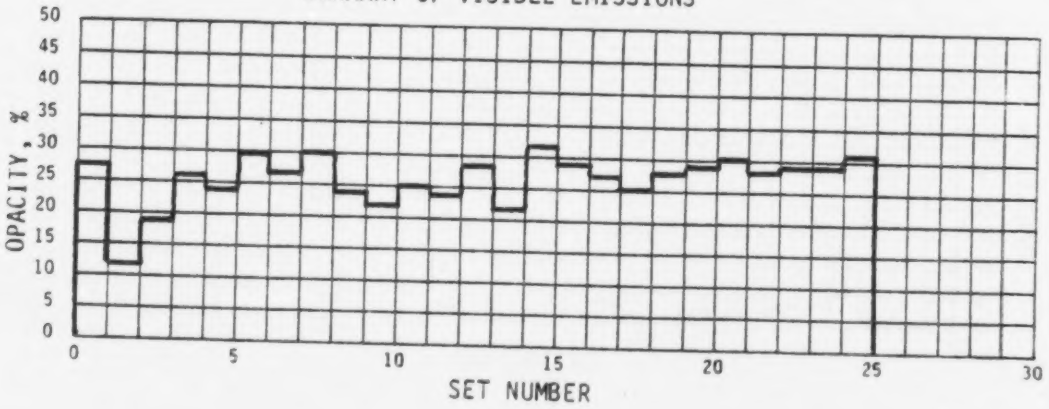


TABLE C-113. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/07/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	East forming stack
Height of observation point	100 ft
Height of point of discharge	15 ft above roof
Direction of observer from discharge point	SSW
Description of background	Green trees
Description of sky	75% clouds
Wind direction	W to E
Wind velocity	10 mph
Color of plume	Blue-gray
Duration of observation	150 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	04:20 p.m.	04:25 p.m.	20	15
2	05:23	05:28	15	11
3	05:29	05:34	20	13
4	05:35	05:40	15	12
5	05:41	05:46	20	15
6	05:47	05:52	15	12
7	05:53	05:58	15	15
8	05:59	06:04	15	14
9	06:05	06:10	15	14
10	06:11	06:16	20	14
11	06:17	06:22	15	13
12	06:23	06:28	15	12
13	06:29	06:34	15	13
14	06:35	06:40	15	10
15	06:41	06:46	15	12
16	06:47	06:52	15	12
17	06:53	06:58	15	13
18	06:59	07:04	20	16
19	07:05	07:10	20	17
20	07:11	07:16	15	15
21	07:17	07:22	15	15
22	07:23	07:28	20	16
23	07:29	07:34	20	15
24	07:35	07:40	15	14
25	07:41	07:46	15	15

SUMMARY OF VISIBLE EMISSIONS

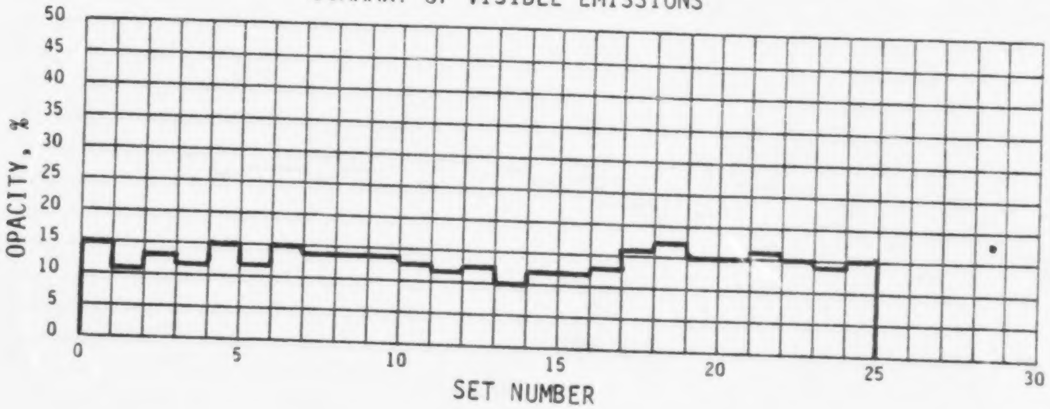


TABLE C-114. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/07/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	West forming stack
Height of observation point	90 ft
Height of point of discharge	15 ft above roof
Direction of observer from discharge point	SSW
Description of background	Trees
Description of sky	50% clouds
Wind direction	W to E
Wind velocity	25 mph
Color of plume	Blue-white
Duration of observation	150 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:11 a.m.	11:16 a.m.	30	26
2	11:17	11:22	30	14
3	11:23	11:28	30	18
4	11:29	11:34	30	25
5	11:35	11:40	30	21
6	11:41	11:46	30	26
7	11:47	11:52	40	27
8	11:53	11:58	35	28
9	11:59	12:04 p.m.	30	23
10	12:08 p.m.	12:13	30	20
11	12:14	12:19	30	24
12	12:22	12:27	35	24
13	12:28	12:33	40	28
14	12:52	12:57	35	27
15	01:01	01:06	35	29
16	01:09	01:14	40	28
17	01:15	01:20	25	25
18	01:25	01:30	30	26
19	01:31	01:36	35	25
20	01:37	01:42	30	28
21	01:43	01:48	30	27
22	02:08	02:13	35	28
23	02:14	02:19	35	28
24	02:21	02:26	35	27
25	02:29	02:34	35	30

SUMMARY OF VISIBLE EMISSIONS

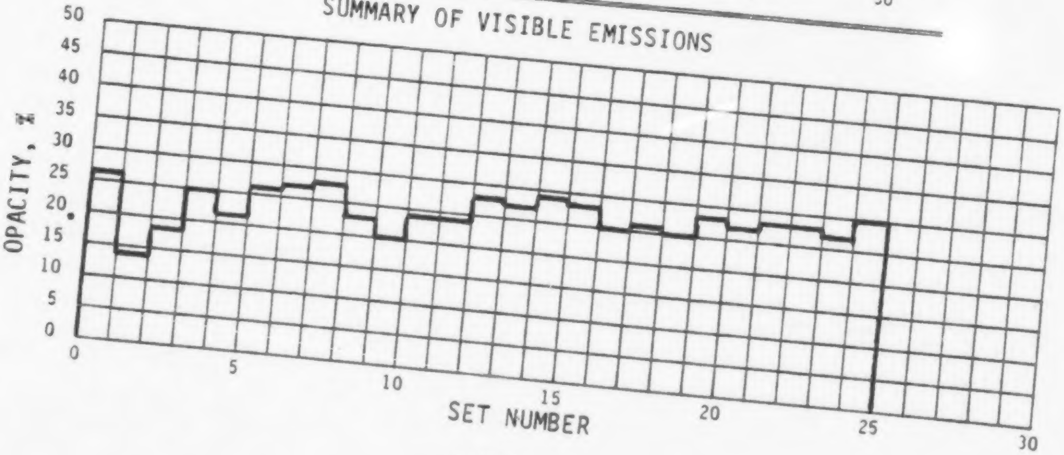


TABLE C-115. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/07/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	West forming stack
Height of observation point	100 ft
Height of point of discharge	15 ft above roof
Direction of observer from discharge point	SSW
Description of background	Green trees
Description of sky	75% clouds
Wind direction	W to E
Wind velocity	10 mph
Color of plume	Blue-gray
Duration of observation	150 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	04:20 p.m.	04:25 p.m.	15	15
2	05:23	05:28	10	7
3	05:29	05:34	15	11
4	05:35	05:40	15	10
5	05:41	05:46	15	12
6	05:47	05:52	15	11
7	05:53	05:58	15	12
8	05:59	06:04	15	11
9	06:05	06:10	15	11
10	06:11	06:16	15	12
11	06:17	06:22	15	12
12	06:23	06:28	15	11
13	06:29	06:34	15	10
14	06:35	06:40	10	10
15	06:41	06:46	15	10
16	06:47	06:52	15	10
17	06:53	06:58	15	11
18	06:59	07:04	15	13
19	07:05	07:10	15	14
20	07:11	07:16	15	12
21	07:17	07:22	15	13
22	07:23	07:28	15	14
23	07:29	07:34	15	13
24	07:35	07:40	15	13
25	07:41	07:46	15	13

SUMMARY OF VISIBLE EMISSIONS

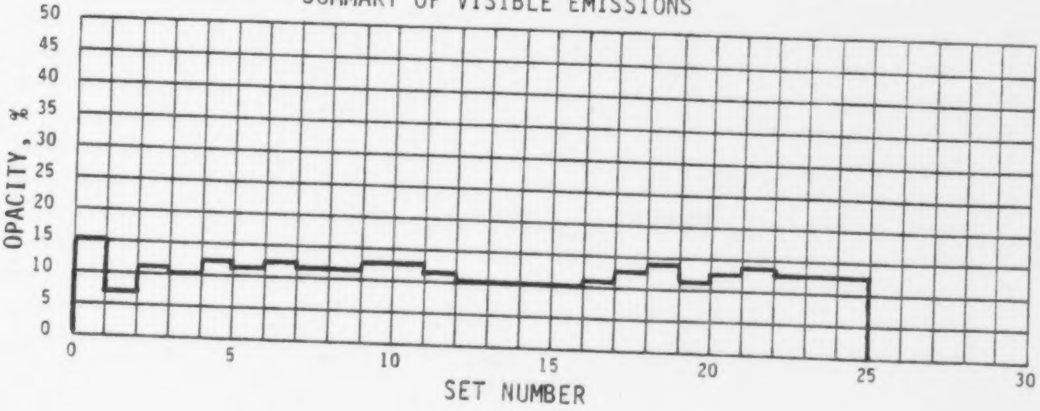


TABLE C-116. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/08/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	East forming stack
Height of observation point	90 ft
Height of point of discharge	15 ft above roof
Direction of observer from discharge point	SSE
Description of background	Green trees
Description of sky	Clear
Wind direction	W to E
Wind velocity	10-15 mph
Color of plume	Blue-gray
Duration of observation	102 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:33 a.m.	10:38 a.m.	35	31
2	10:39	10:44	30	29
3	10:45	10:50	30	24
4	10:51	10:56	30	29
5	10:57	11:02	35	29
6	11:03	11:08	30	28
7	11:09	11:14	30	27
8	11:15	11:20	30	26
9	11:36	11:41	25	21
10	11:42	11:47	25	21
11	11:48	11:53	25	20
12	11:54	11:59	25	20
13	12:19 p.m.	12:24 p.m.	20	18
14	12:25	12:30	25	19
15	12:31	12:36	25	21
16	12:37	12:42	25	21
17	12:43	12:48	20	19

SUMMARY OF VISIBLE EMISSIONS

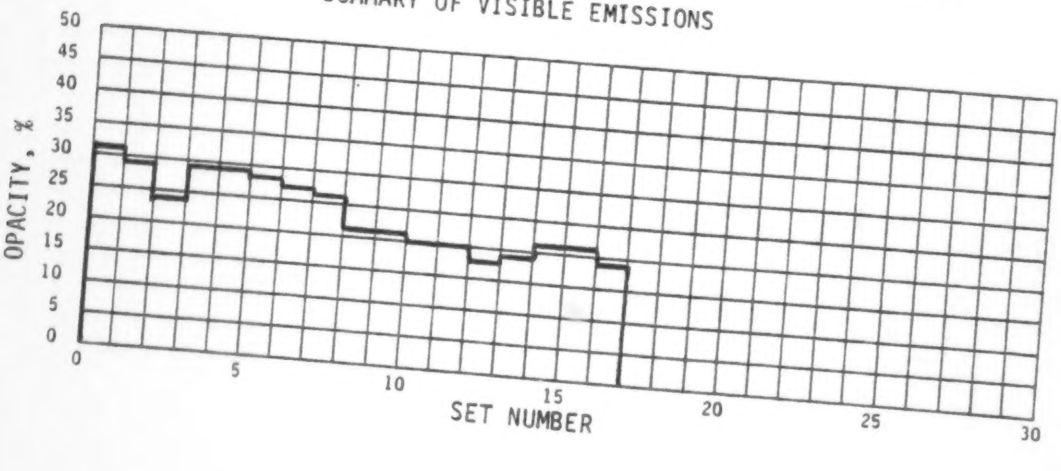


TABLE C-117. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/08/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	West forming stack
Height of observation point	90 ft
Height of point of discharge	15 ft above roof
Direction of observer from discharge point	SSE
Description of background	Green trees
Description of sky	Clear
Wind direction	W to E
Wind velocity	10-15 mph
Color of plume	Blue-gray
Duration of observation	102 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:33 a.m.	10:38 a.m.	30	27
2	10:39	10:44	30	28
3	10:45	10:50	30	22
4	10:51	10:56	30	26
5	10:57	11:02	30	26
6	11:03	11:08	30	26
7	11:09	11:14	30	26
8	11:15	11:20	30	25
9	11:36	11:41	25	22
10	11:42	11:47	25	21
11	11:48	11:53	25	20
12	11:54	11:59	25	20
13	12:19 p.m.	12:24 p.m.	20	18
14	12:25	12:30	25	19
15	12:31	12:36	25	20
16	12:37	12:42	25	21
17	12:43	12:48	20	18

SUMMARY OF VISIBLE EMISSIONS

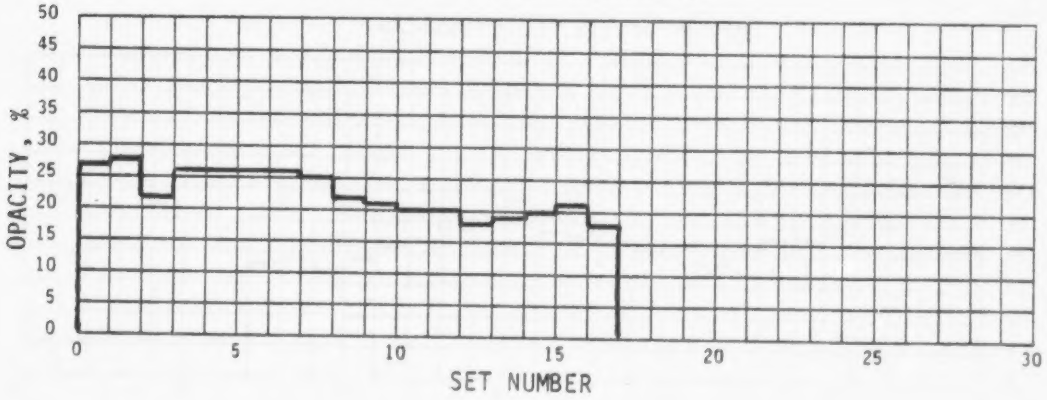


TABLE C-118. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/07/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	HVAF bypass curing stack
Height of observation point	100 ft
Height of point of discharge	5 ft above roof
Direction of observer from discharge point	SSE
Description of background	Green trees
Description of sky	50% clouds
Wind direction	W to E
Wind velocity	15-25 mph
Color of plume	Gray
Duration of observation	138 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:07 a.m.	11:12 a.m.	25	21
2	11:13	11:18	25	20
3	11:19	11:24	35	20
4	11:25	11:30	30	27
5	11:31	11:36	30	24
6	11:37	11:42	25	23
7	11:43	11:48	25	23
8	11:49	11:54	25	21
9	11:55	12:00 p.m.	25	19
10	12:01 p.m.	12:06	25	22
11	12:07	12:12	25	21
12	12:13	12:18	25	22
13	12:19	12:24	25	23
14	12:25	12:30	30	24
15	12:31	12:36	35	28
16	12:42	12:47	35	26
17	01:13	01:18	25	24
18	01:26	01:31	20	15
19	01:38	01:43	25	21
20	01:46	01:51	25	19
21	02:19	02:24	20	17
22	02:25	02:30	25	19
23	02:31	02:36	20	18

SUMMARY OF VISIBLE EMISSIONS

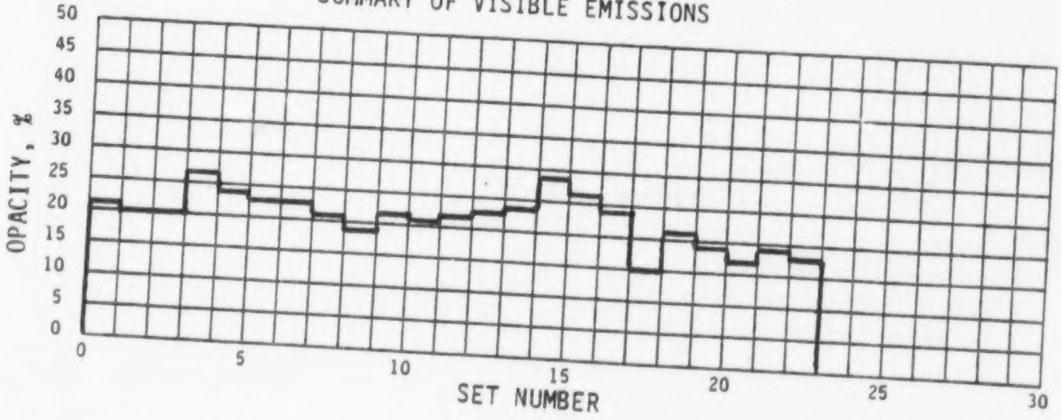


TABLE C-119. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/07/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	HVAF bypass curing stack
Height of observation point	15 ft above stack
Height of point of discharge	5 ft above roof
Direction of observer from discharge point	S
Description of background	Green trees
Description of sky	75% clouds
Wind direction	W to E
Wind velocity	10 mph
Color of plume	White-blue
Duration of observation	144 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	04:20 p.m.	04:25 p.m.	25	19
2	05:23	05:28	20	13
3	05:33	05:38	20	15
4	05:39	05:44	20	14
5	05:47	05:52	20	17
6	05:53	05:58	20	14
7	05:59	06:04	20	15
8	06:05	06:10	15	13
9	06:12	06:17	20	15
10	06:19	06:24	25	16
11	06:25	06:30	20	17
12	06:31	06:36	20	17
13	06:37	06:42	30	20
14	06:43	06:48	25	19
15	06:49	06:54	25	19
16	06:55	07:00	25	17
17	07:01	07:06	20	16
18	07:07	07:12	30	21
19	07:13	07:18	25	20
20	07:19	07:24	25	18
21	07:25	07:30	30	21
22	07:31	07:36	30	20
23	07:37	07:42	25	19
24	07:43	07:48	25	21

SUMMARY OF VISIBLE EMISSIONS

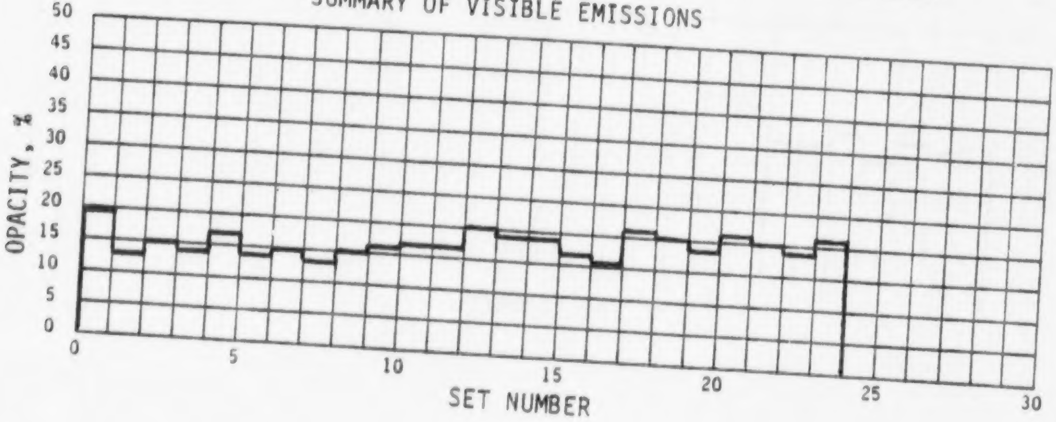


TABLE C-120. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/08/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	HVAF bypass curing stack
Height of observation point	90 ft
Height of point of discharge	5 ft above roof
Direction of observer from discharge point	SSE
Description of background	Green trees
Description of sky	Clear
Wind direction	N to S
Wind velocity	10-15 mph
Color of plume	Blue-gray
Duration of observation	42 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:17 a.m.	11:22 a.m.	30	22
2	11:27	11:32	30	21
3	11:33	11:38	30	22
4	11:39	11:44	20	19
5	11:45	11:50	30	23
6	12:02 p.m.	12:07 p.m.	30	21
7	12:08	12:13	25	21

SUMMARY OF VISIBLE EMISSIONS

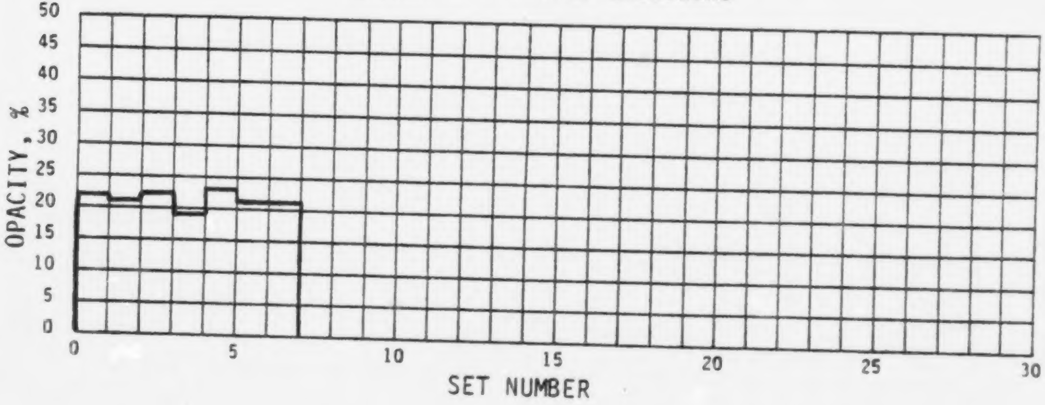


TABLE C-121. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/11/81
Type of plant	Flame attenuation
Distance from observer to discharge point	200 ft
Location of discharge	Curing stack (HVAF without water sprays)
Height of observation point	20 ft
Height of point of discharge	8 ft
Direction of observer from discharge point	SW
Description of background	Not reported
Description of sky	80%-100% clouds
Wind direction	NW to SE
Wind velocity	10-15 mph
Color of plume	Gray-blue
Duration of observation	30 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:04 p.m.	03:09 p.m.	0	0
2	04:08	04:13	0	0
3	04:27	04:32	5	1
4	04:52	04:57	5	1
5	05:01	05:06	0	0

SUMMARY OF VISIBLE EMISSIONS

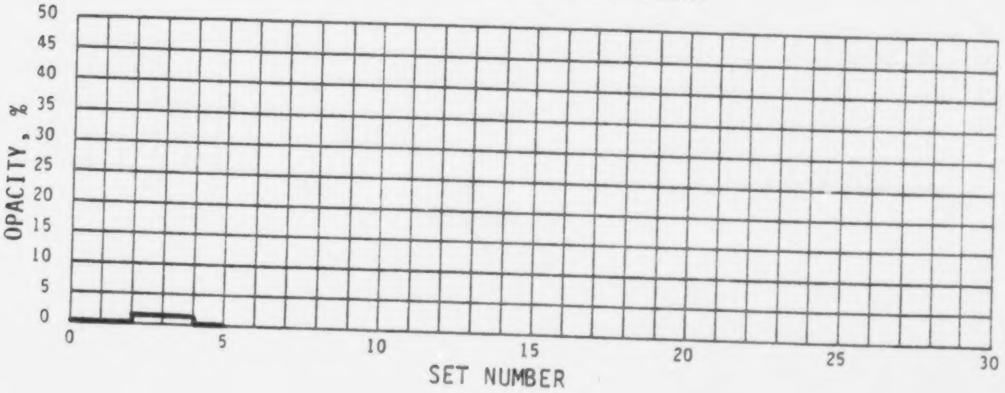


TABLE C-122. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/11/81
Type of plant	Flame attenuation
Distance from observer to discharge point	75 ft
Location of discharge	Curing stack (HVAF without water sprays)
Height of observation point	8 ft
Height of point of discharge	8 ft
Direction of observer from discharge point	ENE
Description of background	Not reported
Description of sky	70%-90% clouds
Wind direction	N to S and S to N
Wind velocity	5-10 mph
Color of plume	None
Duration of observation	42 min

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set No.	Start	End	Maximum in 6 min	6-min average
1 - 7	10:02 a.m.	11:37 a.m.	0	0

All readings were 0 percent opacity during periods of observation.

SUMMARY OF VISIBLE EMISSIONS

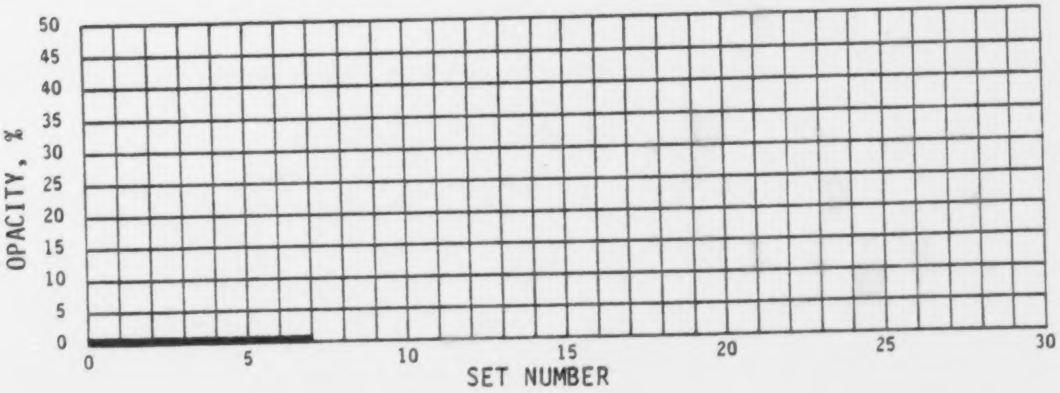


TABLE C-123. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/11/81
Type of plant	Flame attenuation
Distance from observer to discharge point	75 ft
Location of discharge	Curing stack (HVAF without water sprays)
Height of observation point	8 ft
Height of point of discharge	8 ft
Direction of observer from discharge point	ENE
Description of background	Not reported
Description of sky	50%-80% clouds
Wind direction	SW to NE
Wind velocity	10-15 mph
Color of plume	None
Duration of observation	78 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:30 p.m.	12:35 p.m.	0	0
2	12:36	12:41	0	0
3	12:42	12:47	0	0
4	12:48	12:53	0	0
5	12:54	12:59	0	0
6	01:00	01:05	0	0
7	01:06	01:11	0	0
8	01:12	01:17	0	0
9	01:18	01:23	0	0
10	02:00	02:05	5	0
11	02:06	02:11	0	0
12	02:12	02:17	5	0
13	02:18	02:23	0	0

SUMMARY OF VISIBLE EMISSIONS

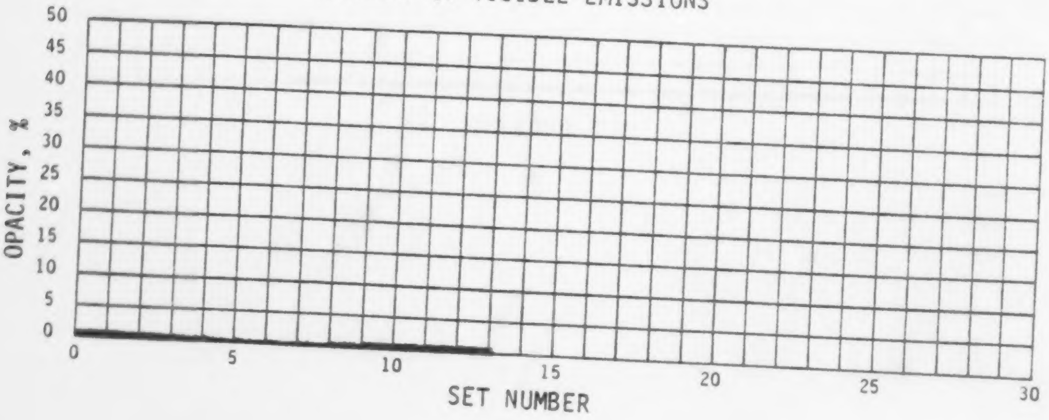


TABLE C-124. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/15/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	Curing stack (HVAF with water sprays)
Height of observation point	2 ft above stack
Height of point of discharge	7 ft above roof
Direction of observer from discharge point	SE
Description of background	Orange/black machinery and green trees
Description of sky	40% clouds
Wind direction	WNW to E
Wind velocity	0-10 mph
Color of plume	None
Duration of observation	138 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 23	01:05 p.m.	03:23 p.m.	0	0

All readings were 0 percent opacity during periods of observation.

SUMMARY OF VISIBLE EMISSIONS

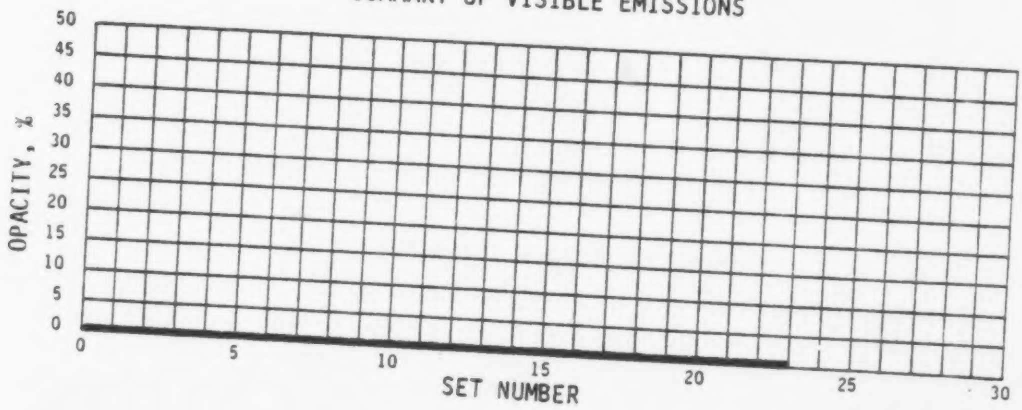


TABLE C-125. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/15/81
Type of plant	Flame attenuation
Distance from observer to discharge point	50 ft
Location of discharge	Curing stack (HVAF with water sprays)
Height of observation point	Stack level
Height of point of discharge	7 ft above roof
Direction of observer from discharge point	SSW
Description of background	Green trees
Description of sky	80% clouds
Wind direction	W to E
Wind velocity	0-5 mph
Color of plume	None
Duration of observation	84 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	04:05 p.m.	04:10 p.m.	0	0
2	04:11	04:16	0	0
3	04:17	04:22	0	0
4	04:23	04:28	0	0
5	04:29	04:34	0	0
6	04:35	04:40	0	0
7	04:41	04:46	0	0
8	05:05	05:10	5	3
9	05:11	05:16	5	3
10	05:17	05:22	5	5
11	05:23	05:28	5	4
12	05:29	05:34	5	3
13	05:35	05:40	5	4
14	05:41	05:46	5	4

SUMMARY OF VISIBLE EMISSIONS

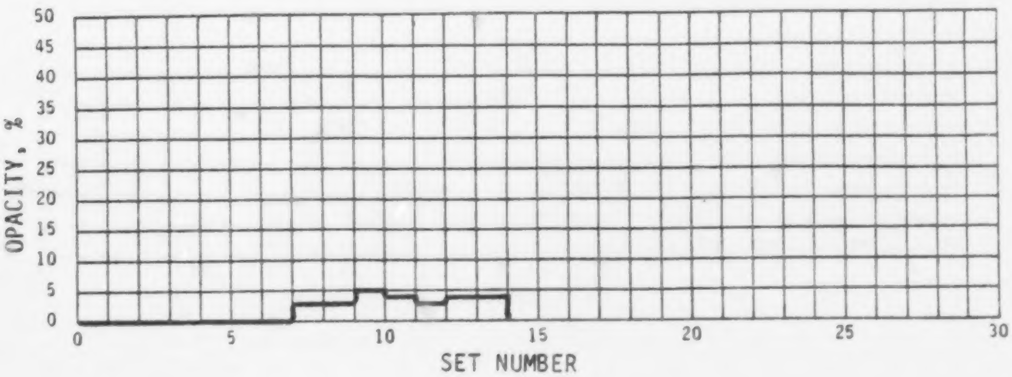


TABLE C-126. SUMMARY OF VISIBLE EMISSIONS--LINE I

Date	07/15/81
Type of plant	Flame attenuation
Distance from observer to discharge point	50 ft
Location of discharge	Curing stack (HVAF with water sprays)
Height of observation point	Stack level
Height of point of discharge	7 ft above roof
Direction of observer from discharge point	SSW
Description of background	Green trees
Description of sky	95% clouds
Wind direction	W to NW
Wind velocity	0-5 mph
Color of plume	Gray
Duration of observation	42 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	07:00 p.m.	07:05 p.m.	5	1
2	08:05	08:10	5	4
3	08:11	08:16	5	3
4	08:17	08:22	5	1
5	08:26	08:31	5	4
6	08:32	08:37	5	4
7	08:38	08:43	5	1

SUMMARY OF VISIBLE EMISSIONS

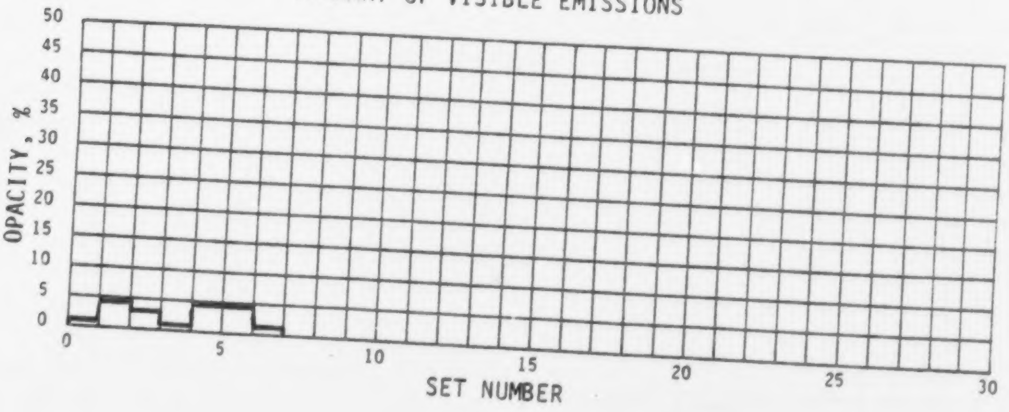


TABLE C-127. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/13/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	East forming stack
Height of observation point	Stack level
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	S
Description of background	Green trees
Description of sky	80% clouds
Wind direction	E to W
Wind velocity	10-20 mph
Color of plume	None
Duration of observation	144 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	01:53 p.m.	01:58 p.m.	5	0
2	01:59	02:04	5	0
3	02:05	02:10	5	0
4	02:11	02:16	5	0
5	02:17	02:22	5	0
6	02:23	02:28	0	0
7	02:29	02:34	0	0
8	02:35	02:40	0	0
9	02:41	02:46	5	0
10	02:47	02:52	0	0
11	02:53	02:58	0	0
12	02:59	03:04	0	0
13	03:05	03:10	0	0
14	03:11	03:16	0	0
15	03:17	03:22	5	0
16	03:23	03:28	0	0
17	03:29	03:34	0	0
18	03:35	03:40	0	0
19	03:41	03:46	0	0
20	03:47	03:52	0	0
21	03:53	03:58	0	0
22	03:59	04:04	0	0
23	04:05	04:10	0	0
24	04:11	04:16	0	0

SUMMARY OF VISIBLE EMISSIONS

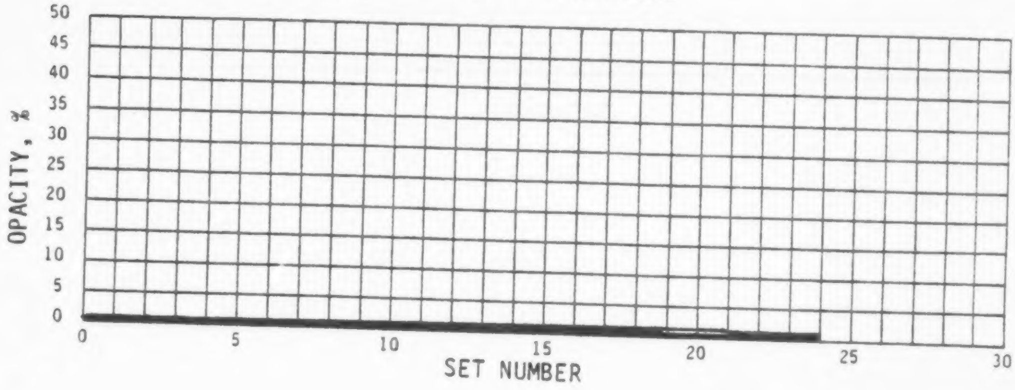


TABLE C-128. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/13/81
Type of plant	Flame attenuation
Distance from observer to discharge point	45 ft
Location of discharge	East forming stack
Height of observation point	8 ft over stack
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	90% clouds
Wind direction	WNW
Wind velocity	15 mph
Color of plume	None
Duration of observation	144 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 24	06:25 p.m.	08:48 p.m.	0	0

All readings were 0 percent opacity during periods of observation.

SUMMARY OF VISIBLE EMISSIONS

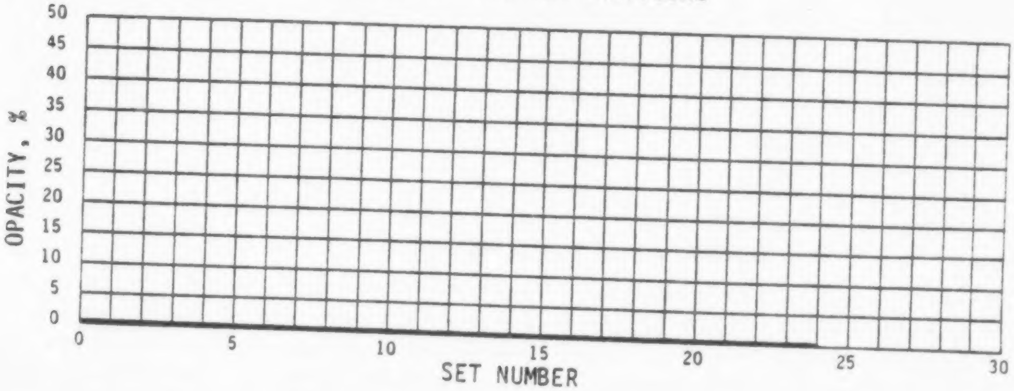


TABLE C-120. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/13/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	West forming stack
Height of observation point	Stack level
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	S
Description of background	Green trees
Description of sky	80% clouds
Wind direction	E to W
Wind velocity	10-20 mph
Color of plume	None
Duration of observation	144 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	01:53 p.m.	01:58 p.m.	0	0
2	01:59	02:04	0	0
3	02:05	02:10	5	0
4	02:11	02:16	5	0
5	02:17	02:22	5	0
6	02:23	02:28	0	0
7	02:29	02:34	5	0
8	02:35	02:40	0	0
9	02:41	02:46	0	0
10	02:47	02:52	0	0
11	02:53	02:58	0	0
12	02:59	03:04	0	0
13	03:05	03:10	0	0
14	03:11	03:16	0	0
15	03:17	03:22	5	0
16	03:23	03:28	0	0
17	03:29	03:34	0	0
18	03:35	03:40	5	0
19	03:41	03:46	0	0
20	03:47	03:52	0	0
21	03:53	03:58	0	0
22	03:59	04:04	0	0
23	04:05	04:10	0	0
24	04:11	04:16	0	0

SUMMARY OF VISIBLE EMISSIONS

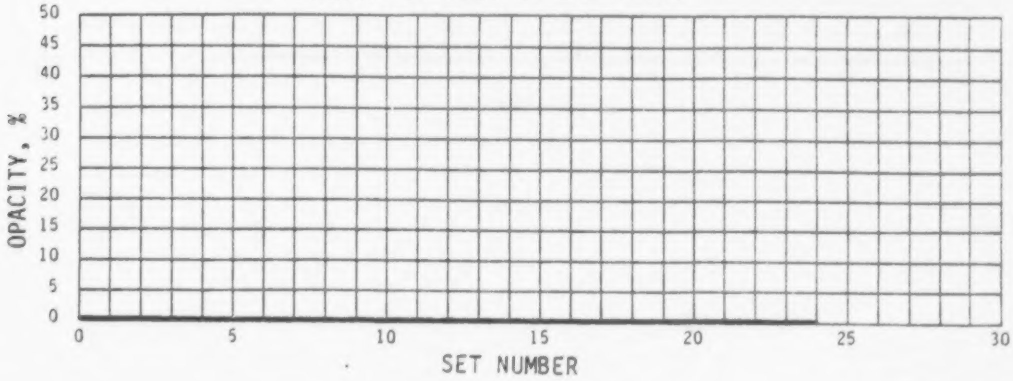


TABLE C-13G. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/13/81
Type of plant	Flame attenuation
Distance from observer to discharge point	45 ft
Location of discharge	West forming stack
Height of observation point	8 ft over stack
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	90% clouds
Wind direction	WNW
Wind velocity	15 mph
Color of plume	None
Duration of observation	144 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 24	06:25 p.m.	08:48 p.m.	0	0

All readings were 0 percent opacity during periods of observation.

SUMMARY OF VISIBLE EMISSIONS

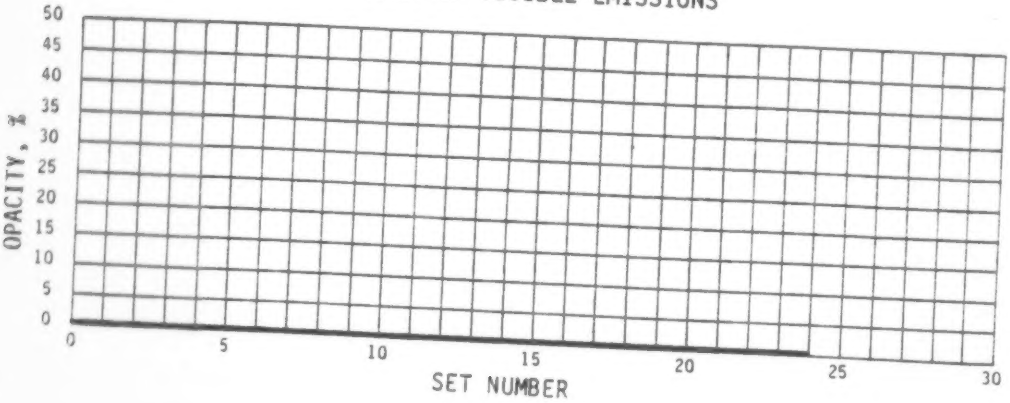


TABLE C-131. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/13/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	Curing stack (HVAF without water sprays)
Height of observation point	90 ft above ground
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	N
Description of background	Green trees
Description of sky	90% clouds
Wind direction	NW to SE
Wind velocity	15-20 mph
Color of plume	Blue-gray
Duration of observation	42 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	01:54 p.m.	01:59 p.m.	10	3
2	02:06	02:11	5	3
3	02:20	02:25	5	4
4	02:26	02:31	5	3
5	02:46	02:51	5	4
6	02:52	02:57	5	1
7	03:29	03:34	5	3

SUMMARY OF VISIBLE EMISSIONS

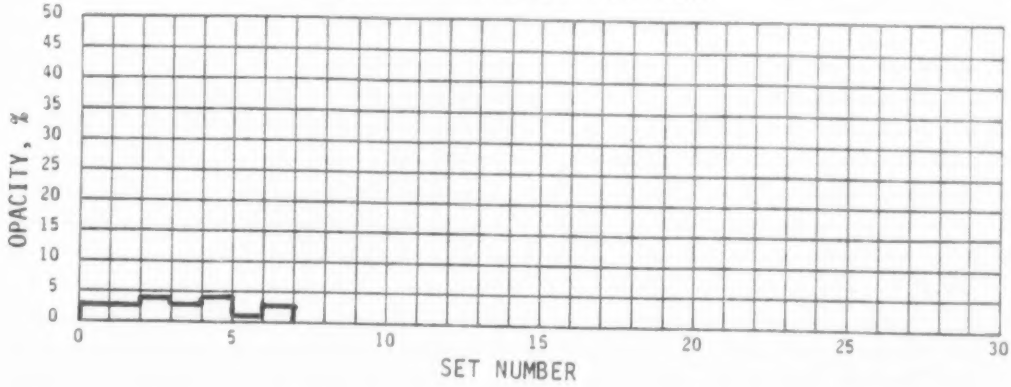


TABLE C-132. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/13/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	Curing stack (HVAF without water sprays)
Height of observation point	75 ft above ground
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	Overcast
Wind direction	NW to SE
Wind velocity	10-15 mph
Color of plume	Light gray
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	06:26 p.m.	06:31 p.m.	5	2
2	06:35	06:40	5	2
3	06:42	06:47	5	1
4	06:59	07:04	5	1
5	07:11	07:16	5	3
6	07:17	07:22	5	1
7	07:32	07:37	5	1
8	07:50	07:55	5	1
9	08:00	08:05	5	3
10	08:08	08:13	5	1

SUMMARY OF VISIBLE EMISSIONS

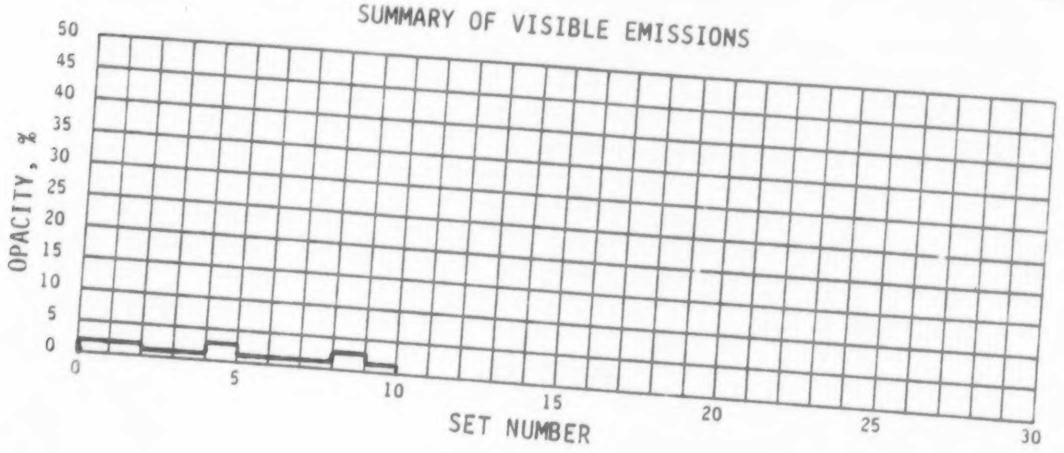


TABLE C-133. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/14/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	East forming stack
Height of observation point	Stack level
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	S
Description of background	Green trees
Description of sky	Overcast
Wind direction	WNW
Wind velocity	10 mph
Color of plume	None
Duration of observation	138 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 22	10:00 a.m.	12:11 a.m.	0	0

All readings were 0 percent opacity during periods of observation except for one 15-second reading of 15 percent opacity.

SUMMARY OF VISIBLE EMISSIONS

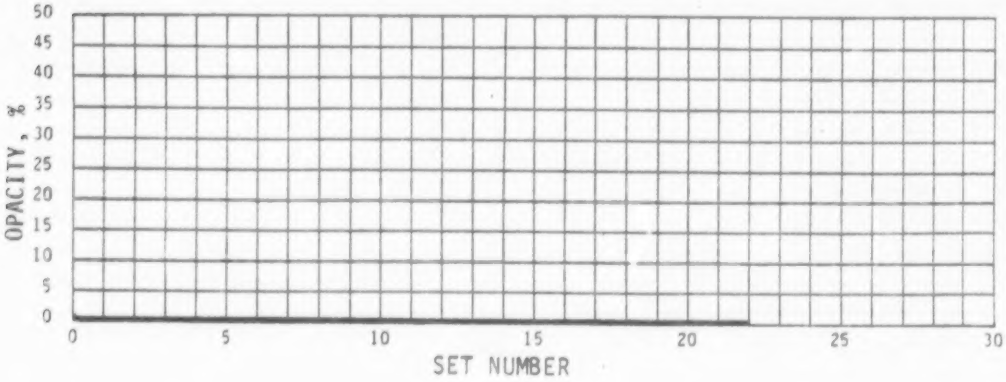


TABLE C-134. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/14/81
Type of plant	Flame attenuation
Distance from observer to discharge point	50 ft
Location of discharge	East forming stack
Height of observation point	75 ft
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	Slightly overcast
Wind direction	W to E
Wind velocity	10 mph
Color of plume	None
Duration of observation	132 min

SUMMARY OF AVERAGE OPACITY

	Time		Opacity	
Set No.	Start	End	Maximum in 6 min	6-min average
1 - 22	02:10 p.m.	04:21 p.m.	0	0

All readings were 0 percent opacity during periods of observation.

SUMMARY OF VISIBLE EMISSIONS

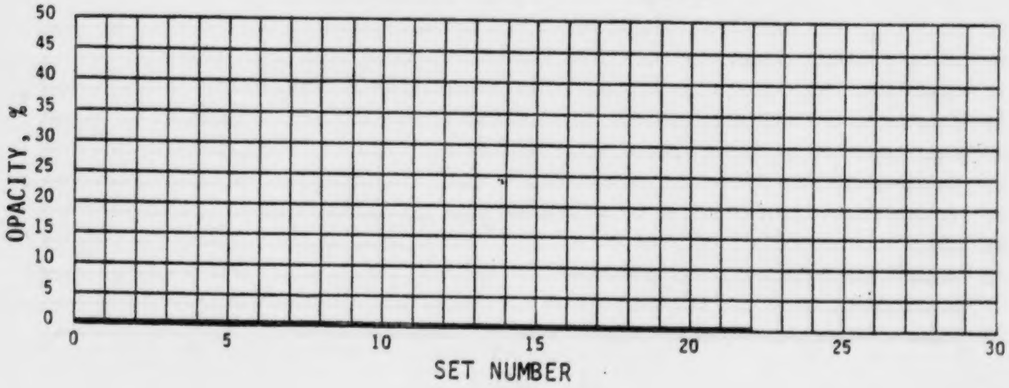


TABLE C-135. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/14/81
Type of plant	Flame attenuation
Distance from observer to discharge point	1,300 ft
Location of discharge	West forming stack
Height of observation point	Stack level
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	S
Description of background	Green trees
Description of sky	Overcast
Wind direction	WNW
Wind velocity	10 mph
Color of plume	None
Duration of observation	132 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 22	10:00 a.m.	12:11 a.m.	0	0

All readings were 0 percent opacity during periods of observation except for three 15-second readings of 5 percent opacity.

SUMMARY OF VISIBLE EMISSIONS

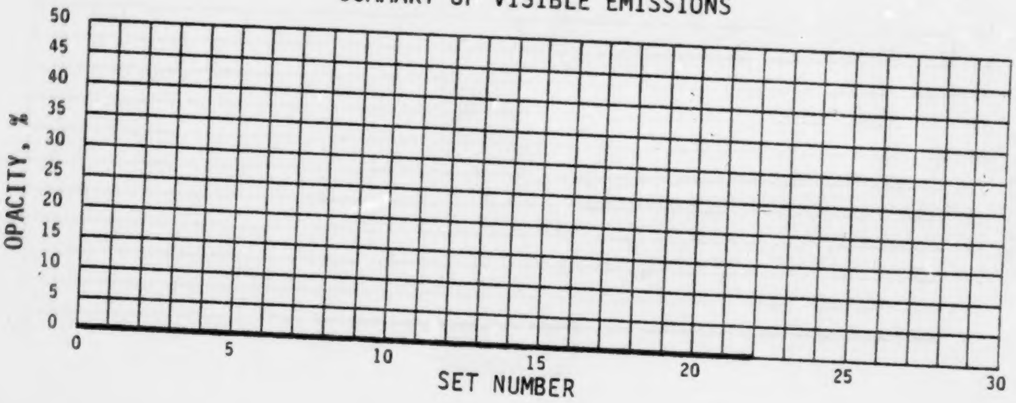


TABLE C-136. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/14/81
Type of plant	Flame attenuation
Distance from observer to discharge point	50 ft
Location of discharge	West forming stack
Height of observation point	75 ft
Height of point of discharge	20 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	Slightly overcast
Wind direction	W to E
Wind velocity	10 mph
Color of plume	None
Duration of observation	132 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 22	02:10 p.m.	04:21 p.m.	0	0

All readings were 0 percent opacity during periods of observation.

SUMMARY OF VISIBLE EMISSIONS

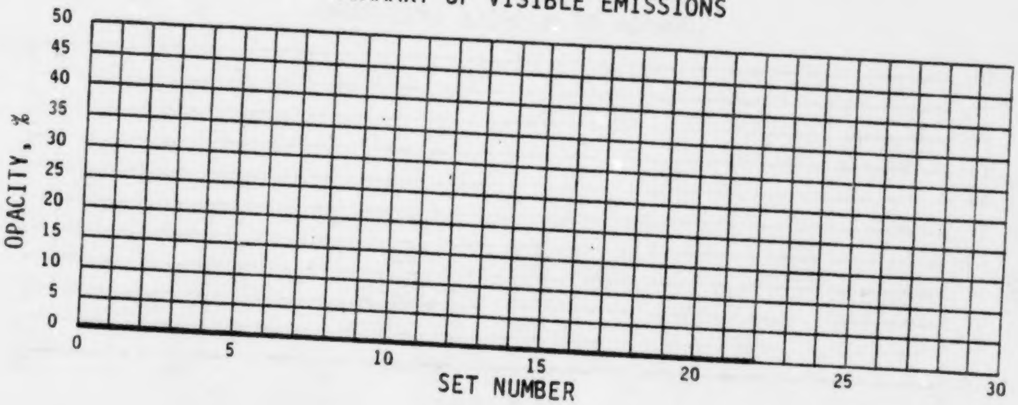


TABLE C-137. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/14/81
Type of plant	Flame attenuation
Distance from observer to discharge point	100 ft
Location of discharge	Curing stack (HVAF without water sprays)
Height of observation point	60 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	SE
Description of background	Green trees
Description of sky	Slight overcast
Wind direction	NW to SE
Wind velocity	10 mph
Color of plume	Light gray-blue
Duration of observation	66 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	10:04 a.m.	10:09 a.m.	5	2
2	10:13	10:18	5	3
3	10:23	10:28	5	3
4	10:42	10:47	5	2
5	10:58	11:03	5	2
6	11:10	11:15	5	3
7	11:16	11:21	5	2
8	11:22	11:27	5	3
9	11:30	11:35	5	3
10	11:37	11:42	5	1
11	11:46	11:51	5	2

SUMMARY OF VISIBLE EMISSIONS

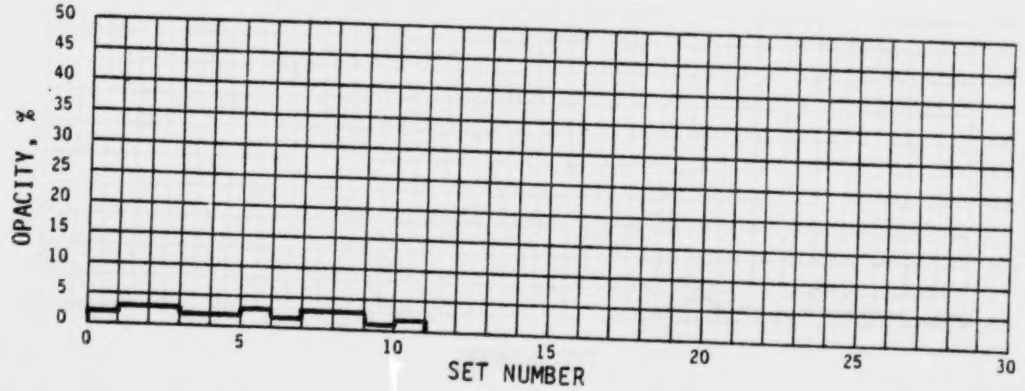


TABLE C-138. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/14/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	Curing stack (HVAF without water sprays)
Height of observation point	75 ft
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	W
Description of background	Green trees
Description of sky	Slight overcast
Wind direction	W to E
Wind velocity	10 mph
Color of plume	Light gray
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	02:10 p.m.	02:15 p.m.	5	2
2	02:16	02:21	5	1
3	02:22	02:27	5	2
4	02:33	02:38	5	2
5	02:39	02:44	5	2
6	03:07	03:12	5	2
7	03:16	03:21	5	2
8	03:22	03:27	5	2
9	03:42	03:47	5	3
10	04:08	04:13	5	2

SUMMARY OF VISIBLE EMISSIONS

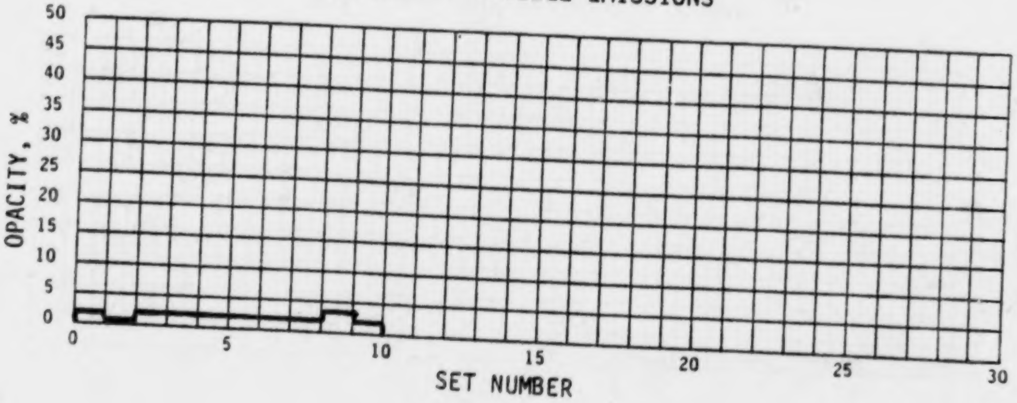


TABLE C-139. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/15/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	Curing stack (HVAF with water sprays)
Height of observation point	70 ft above ground
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	SE
Description of background	Green trees
Description of sky	85% clouds
Wind direction	NE to SW
Wind velocity	5-10 mph
Color of plume	Light gray
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	01:40 p.m.	01:45 p.m.	5	2
2	01:50	01:55	5	2
3	02:36	02:41	5	1
4	02:55	03:00	5	2
5	03:01	03:06	10	5
6	03:20	03:25	10	5
7	03:26	03:31	5	2
8	03:32	03:37	5	1
9	03:38	03:43	5	2
10	03:44	03:49	5	2

SUMMARY OF VISIBLE EMISSIONS

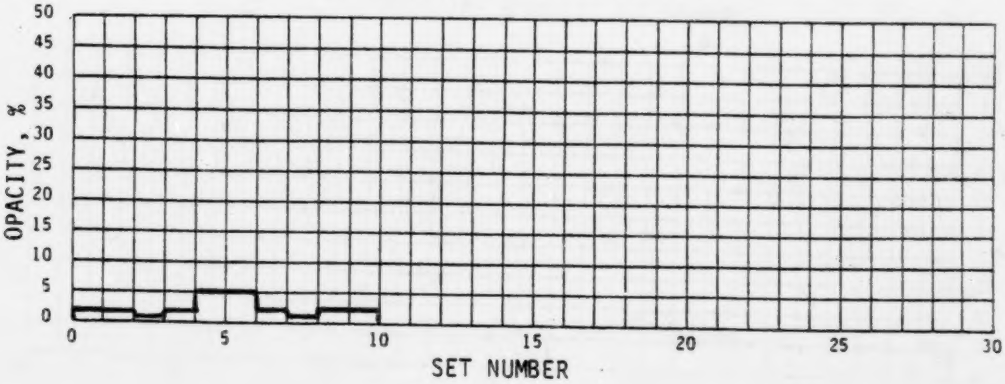


TABLE C-140. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/15/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	Curing stack (HVAF with water sprays)
Height of observation point	75 ft above ground
Height of point of discharge	6 ft above roof
Direction of observer from discharge point	SW
Description of background	Green trees
Description of sky	75% clouds
Wind direction	W to E
Wind velocity	5 mph
Color of plume	Light gray
Duration of observation	78 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	05:25 p.m.	05:30	10	6
2	05:31	05:36	10	5
3	05:37	05:42	5	5
4	05:43	05:48	5	5
5	06:07	06:12	5	5
6	06:13	06:18	5	5
7	06:22	06:27	5	5
8	06:34	06:39	10	6
9	07:58	08:03	10	5
10	08:05	08:10	10	10
11	08:11	08:16	10	8
12	08:29	08:34	10	6
13	08:40	08:45	5	5

SUMMARY OF VISIBLE EMISSIONS

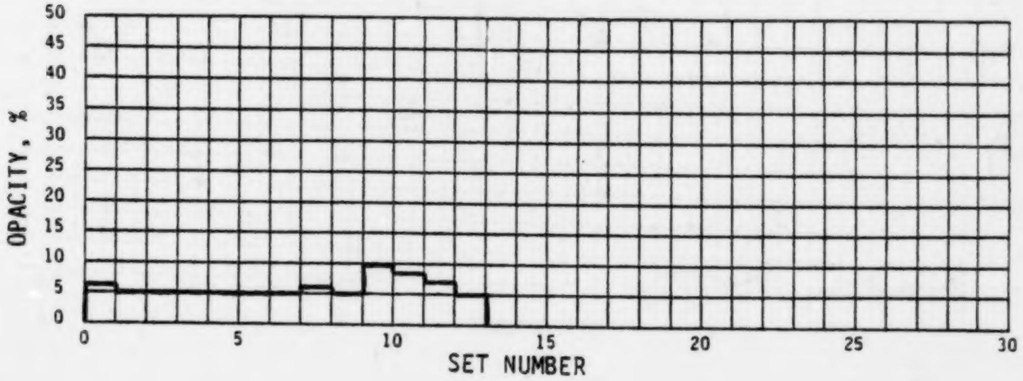


TABLE C-141. SUMMARY OF VISIBLE EMISSIONS--LINE J

Date	07/16/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	Curing stack (HVAF with water sprays)
Height of observation point	5 ft above stack
Height of point of discharge	5 ft above roof
Direction of observer from discharge point	SE
Description of background	Not reported
Description of sky	10% clouds
Wind direction	WNW
Wind velocity	5-10 mph
Color of plume	Blue-gray
Duration of observation	12 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:00 p.m.	12:05 p.m.	5	1
2	12:39	12:44	5	3

SUMMARY OF VISIBLE EMISSIONS

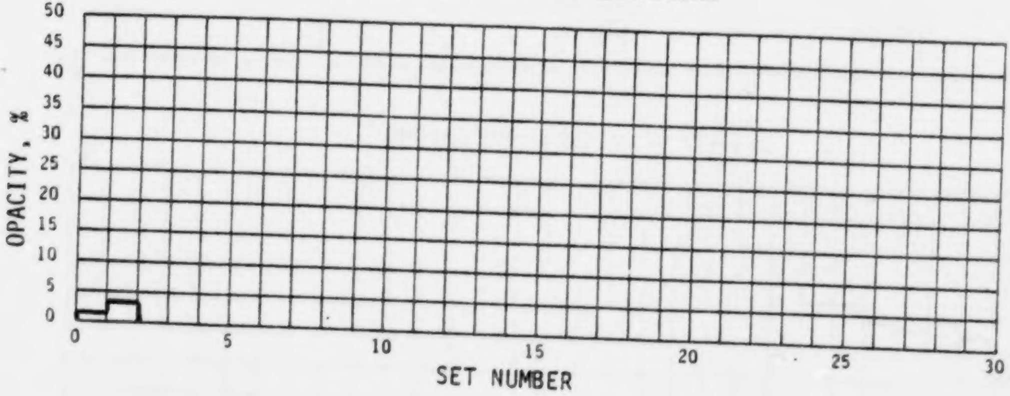


TABLE C-142. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/27/81
Type of plant	Flame attenuation
Distance from observer to discharge point	100 ft
Location of discharge	North forming stack
Height of observation point	30 ft above stack top
Height of point of discharge	80 ft
Direction of observer from discharge point	NE
Description of background	Substation
Description of sky	Overcast
Wind direction	NNE
Wind velocity	25 mph
Color of plume	Light blue
Duration of observation	48 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	03:56 p.m.	04:01 p.m.	30	21
2	04:02	04:07	35	27
3	04:17	04:22	40	29
4	04:30	04:35	30	28
5	05:15	05:20	35	29
6	05:23	05:28	35	32
7	05:33	05:38	35	32
8	05:40	05:45	40	35

SUMMARY OF VISIBLE EMISSIONS

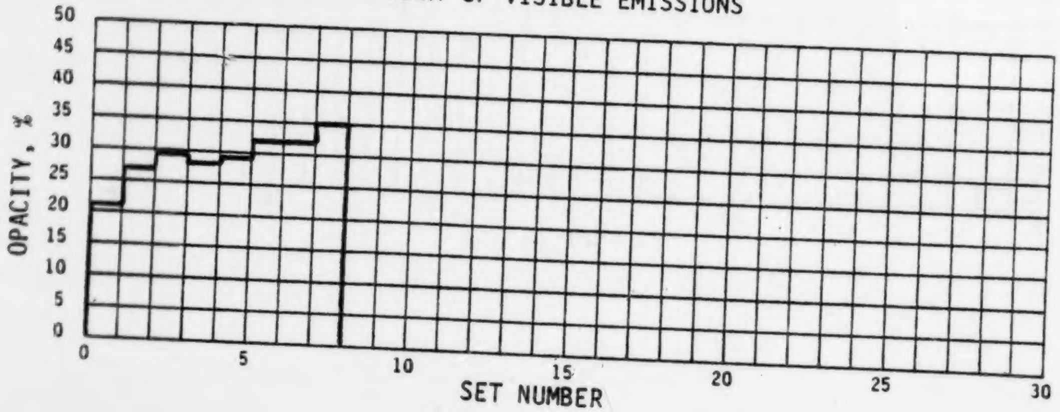


TABLE C-143. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/27/81
Type of plant	Flame attenuation
Distance from observer to discharge point	80 ft
Location of discharge	South forming stack
Height of observation point	50 ft
Height of point of discharge	80 ft
Direction of observer from discharge point	NNE
Description of background	Brown stack
Description of sky	Overcast
Wind direction	NNE
Wind velocity	35 mph
Color of plume	Blue
Duration of observation	54 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	03:56 p.m.	04:01 p.m.	20	9
2	04:02	04:07	20	10
3	04:20	04:25	25	15
4	04:30	04:35	30	20
5	04:50	04:55	20	15
6	05:16	05:21	25	19
7	05:24	05:29	45	25
8	05:33	05:38	30	26
9	05:40	05:45	30	26

SUMMARY OF VISIBLE EMISSIONS

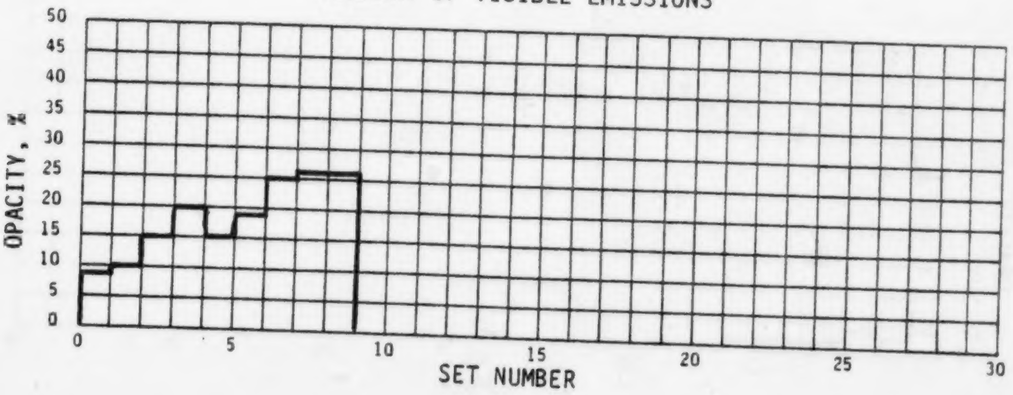


TABLE C-144. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/28/81
Type of plant	Flame attenuation
Distance from observer to discharge point	100 ft
Location of discharge	North forming stack
Height of observation point	30 ft above stack top
Height of point of discharge	80 ft
Direction of observer from discharge point	NE
Description of background	Substation
Description of sky	50% clouds
Wind direction	NNE
Wind velocity	20 mph
Color of plume	Light blue
Duration of observation	54 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:30 a.m.	09:35 a.m.	5	4
2	09:50	09:55	5	3
3	10:10	10:15	5	4
4	10:30	10:35	5	2
5	10:45	10:50	5	2
6	11:01	11:06	5	2
7	11:19	11:24	5	2
8	11:43	11:48	5	1
9	12:00 p.m.	12:05 p.m.	5	4

SUMMARY OF VISIBLE EMISSIONS

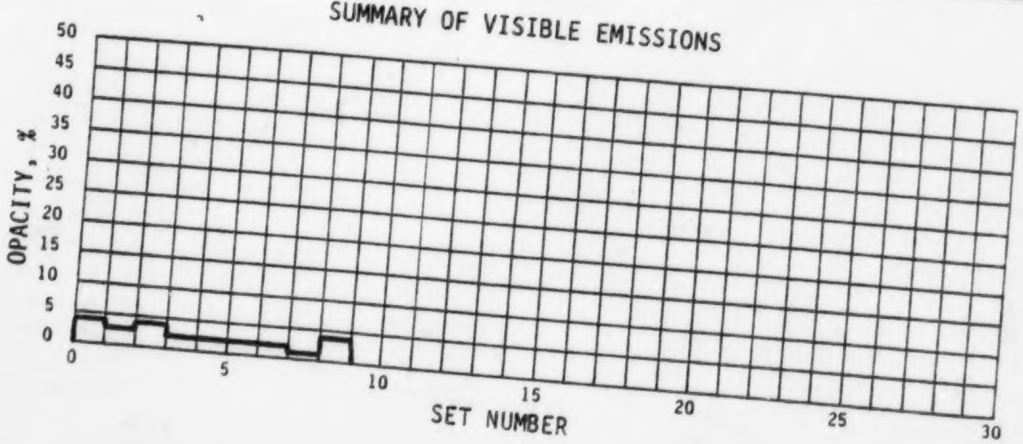


TABLE C-145. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/28/81
Type of plant	Flame attenuation
Distance from observer to discharge point	150 ft
Location of discharge	North forming stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	NW
Description of background	Sky
Description of sky	50% clouds
Wind direction	NNE
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	54 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	02:30 p.m.	02:35 p.m.	5	4
2	02:44	02:49	5	1
3	03:07	03:12	0	0
4	03:20	03:25	0	0
5	03:36	03:41	0	0
6	03:50	03:55	5	0
7	04:07	04:12	5	1
8	04:22	04:27	0	0
9	04:37	04:42	0	0

SUMMARY OF VISIBLE EMISSIONS

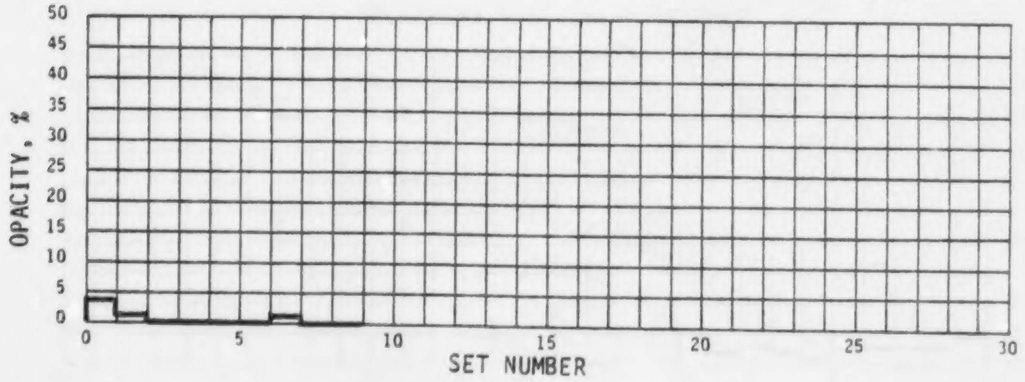


TABLE C-146. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/28/81
Type of plant	Flame attenuation
Distance from observer to discharge point	100 ft
Location of discharge	South forming stack
Height of observation point	30 ft above stack top
Height of point of discharge	80 ft
Direction of observer from discharge point	NE
Description of background	Stack
Description of sky	50% clouds
Wind direction	NNE
Wind velocity	20 mph
Color of plume	Light blue
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:09 a.m.	09:14 a.m.	10	5
2	09:40	09:45	5	3
3	10:00	10:05	10	3
4	10:19	10:24	5	3
5	10:38	10:43	5	3
6	10:53	10:58	5	1
7	11:10	11:15	5	2
8	11:30	11:35	5	3
9	11:50	11:55	5	2
10	12:09	12:14	10	5

SUMMARY OF VISIBLE EMISSIONS

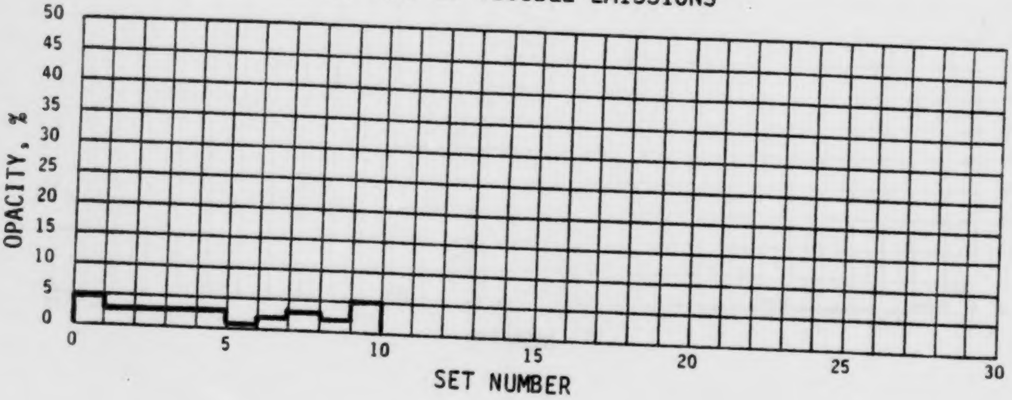


TABLE C-147. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/28/81
Type of plant	Flame attenuation
Distance from observer to discharge point	150 ft
Location of discharge	South forming stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	NW
Description of background	Sky
Description of sky	50% clouds
Wind direction	NNE
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 10	02:38 p.m.	05:24 p.m.	0	0

Readings were 0 percent opacity during all periods of observation.

SUMMARY OF VISIBLE EMISSIONS

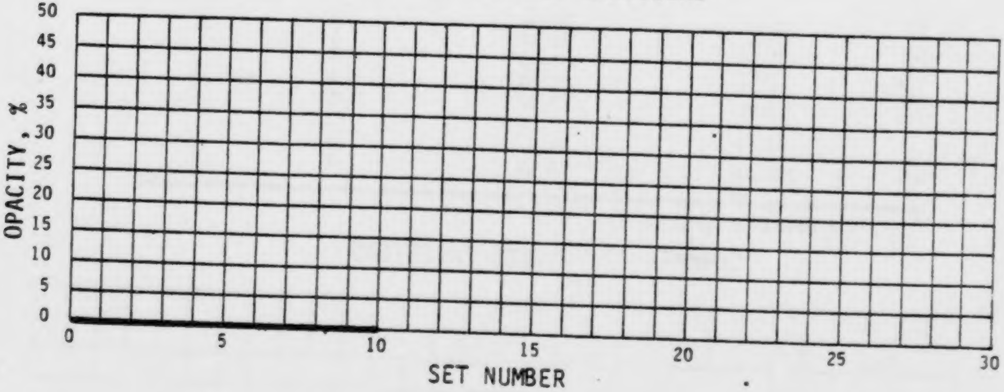


TABLE C-148. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	65 ft location 1; 70 ft location 2
Location of discharge	East curing stack
Height of observation point	12 ft both locations
Height of point of discharge	30 ft
Direction of observer from discharge point	SE
Description of background	Sky
Description of sky	10% clouds both locations
Wind direction	SSW
Wind velocity	10 mph location 1; 25 mph location 2
Color of plume	Light blue
Duration of observation	78 min location 1; 24 min location 2

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:41 p.m.	12:46 p.m.	5	5
2	12:52	12:57	10	8
3	01:04	01:09	10	7
4	01:16	01:21	10	5
5	01:28	01:33	10	7
6	01:34	01:39	10	10
7	01:41	01:46	10	7
8	02:30	02:35	5	5
9	02:42	02:47	10	2
10	02:51	02:56	5	1
11	02:57	03:02	0	0
12	03:09	03:14	5	4
13	03:21	03:26	5	5
14[a]	03:33	03:38	5	5
15	03:45	03:50	5	2
16	03:57	04:02	0	0
17	04:04	04:09	0	0

[a] Observer moved to location 2.

SUMMARY OF VISIBLE EMISSIONS

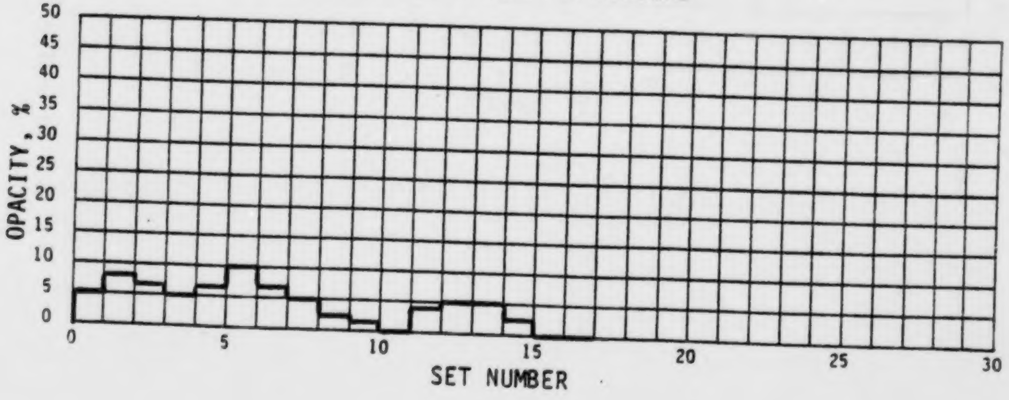


TABLE C-149. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	75 ft
Location of discharge	East curing stack
Height of observation point	12 ft
Height of point of discharge	30 ft
Direction of observer from discharge point	SSW
Description of background	Brown and blue stack
Description of sky	80% clouds
Wind direction	SSE
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	54 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	05:00 p.m.	05:05 p.m.	10	4
2				3
3				6
4	06:00	06:05	10	5
5				7
6				7
7				5
8				6
9	07:54	07:59	5	5

SUMMARY OF VISIBLE EMISSIONS

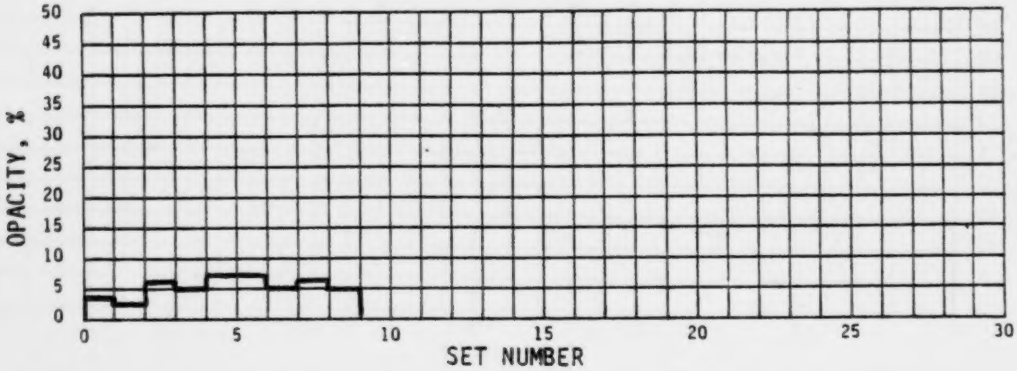


TABLE C-150. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	90 ft
Location of discharge	West curing stack
Height of observation point	15 ft
Height of point of discharge	35 ft
Direction of observer from discharge point	SE
Description of background	Brown stack
Description of sky	Clear
Wind direction	S to N
Wind velocity	10 mph
Color of plume	White
Duration of observation	66 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:40 p.m.	12:45 p.m.	15	15
2			15	15
3			15	15
4			15	15
5			15	15
6			15	15
7			15	15
8			15	13
9			15	14
10			15	15
11	03:55	04:00	15	15

SUMMARY OF VISIBLE EMISSIONS

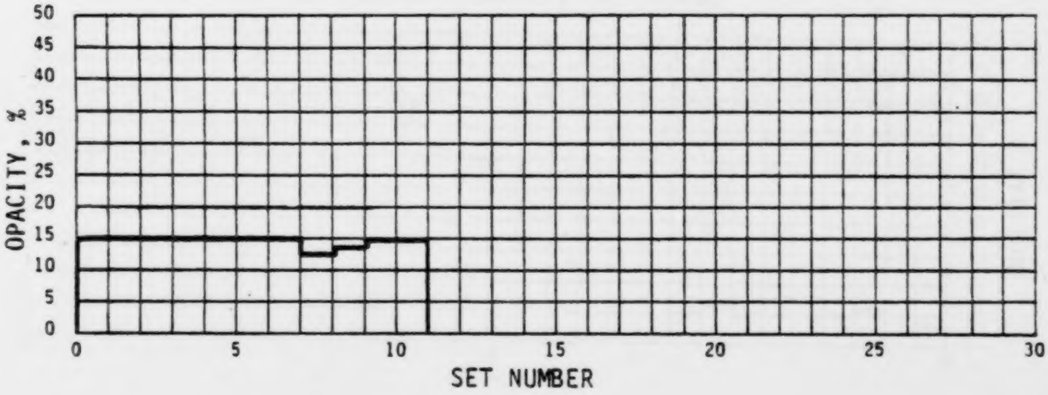


TABLE C-151. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	West curing stack
Height of observation point	Ground level
Height of point of discharge	30 ft
Direction of observer from discharge point	NW
Description of background	Brown stack
Description of sky	90% clouds
Wind direction	N to S
Wind velocity	5 mph
Color of plume	White
Duration of observation	54 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	05:45 p.m.	05:50 p.m.	15	12
2	05:51	05:56	15	14
3	05:57	06:02	15	15
4	06:03	06:08	15	15
5	06:09	06:14	15	15
6	06:15	06:20	15	15
7	06:21	06:26	15	15
8	07:38	07:43	15	15
9	07:44	07:49	15	15

SUMMARY OF VISIBLE EMISSIONS

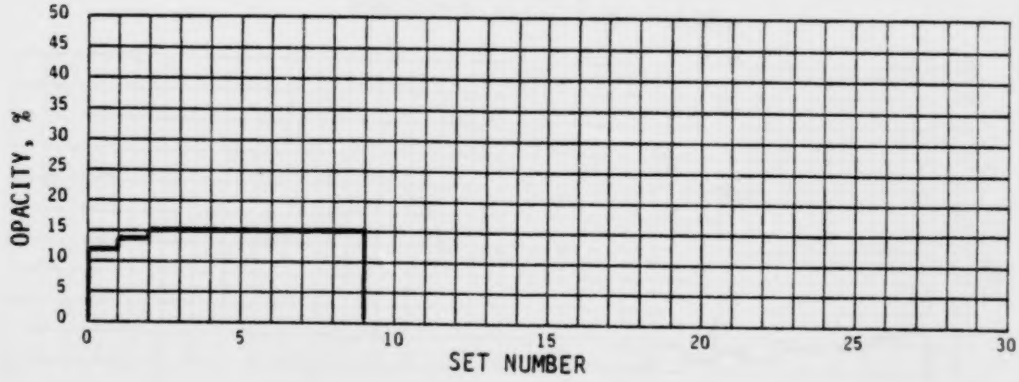


TABLE C-152. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	80 ft location 1; 150 ft location 2
Location of discharge	North forming stack
Height of observation point	45 ft location 1; Ground level location 2
Height of point of discharge	80 ft
Direction of observer from discharge point	SE location 1; NW location 2
Description of background	Sky
Description of sky	10% clouds location 1; 30% clouds location 2
Wind direction	SSW
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	30 min location 1; 42 min location 2

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:30 p.m.	12:35	10	7
2	12:45	12:50	10	6
3	01:00	01:05	5	4
4	01:14	01:19	10	4
5	01:40	01:45	5	4
6[a]	02:00	02:05	5	2
7	02:14	02:19	5	3
8	02:30	02:35	5	2
9	02:44	02:49	5	4
10	03:00	03:05	0	0
11	03:13	03:18	0	0
12	04:04	04:09	0	0

[a] Observer moved to location 2.

SUMMARY OF VISIBLE EMISSIONS

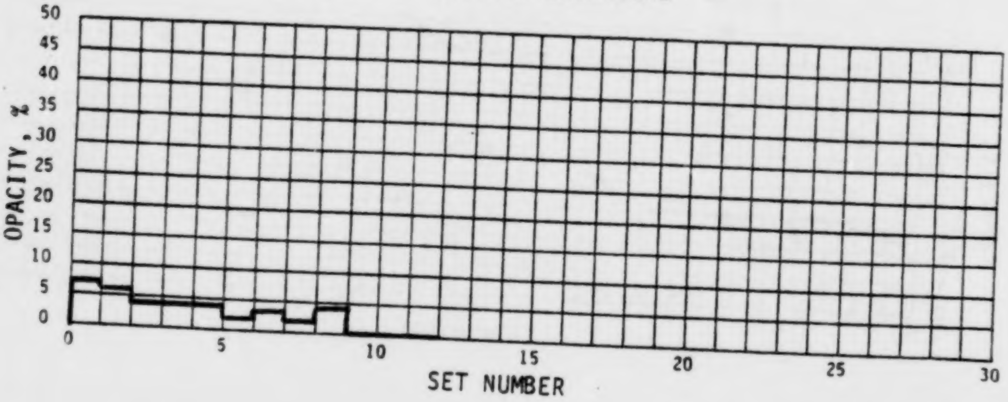


TABLE C-153. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	150 ft
Location of discharge	North forming stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	NW
Description of background	Sky
Description of sky	20%-90% clouds
Wind direction	S to SSW
Wind velocity	10 mph
Color of plume	Not reported
Duration of observation	54 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 9	05:37 p.m.	07:58 p.m.	0	0

Readings were 0 percent opacity during all periods of observation.

SUMMARY OF VISIBLE EMISSIONS

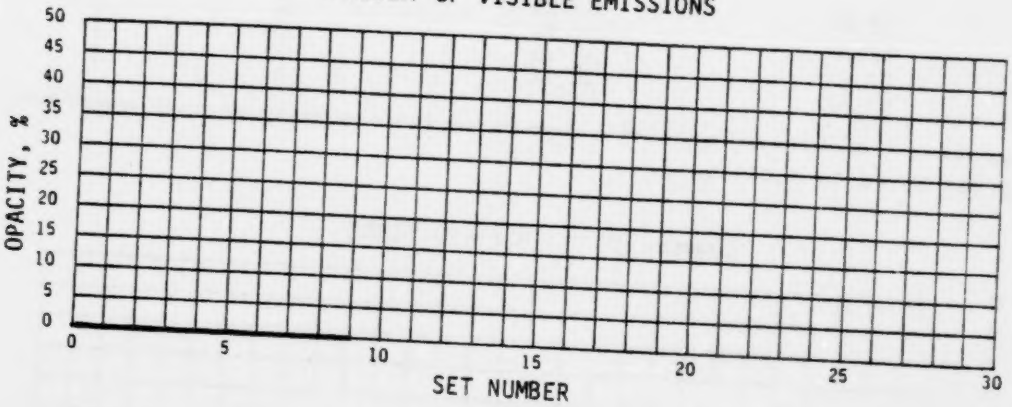


TABLE C-154. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	80 ft location 1; 150 ft location 2
Location of discharge	South forming stack
Height of observation point	45 ft location 1; Ground level location 2
Height of point of discharge	80 ft
Direction of observer from discharge point	SE location 1; NW location 2
Description of background	Sky
Description of sky	10% clouds location 1; 30% clouds location 2
Wind direction	SSW
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	18 min location 1; 36 min location 2

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:38 p.m.	12:43 p.m.	5	5
2	01:07	01:12	5	4
3	01:20	01:25	10	3
4[a]	01:50	01:55	5	2
5	02:07	02:12	5	1
6	02:20	02:25	5	1
7	02:37	02:42	0	0
8	02:51	02:56	5	4
9	03:06	03:11	5	1

[a] Observer moved to location 2.

SUMMARY OF VISIBLE EMISSIONS

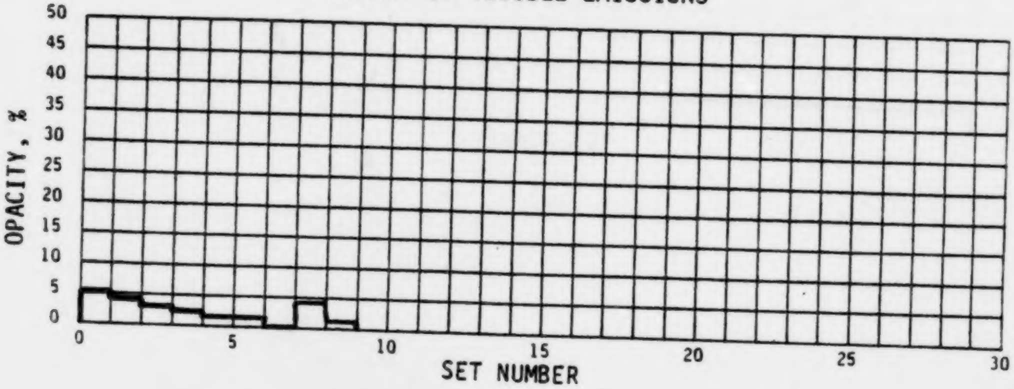


TABLE C-155. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/29/81
Type of plant	Flame attenuation
Distance from observer to discharge point	150 ft
Location of discharge	South forming stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	NW
Description of background	Sky
Description of sky	20%-90% clouds
Wind direction	S
Wind velocity	10 mph
Color of plume	Not reported
Duration of observation	48 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1 - 8	05:30 p.m.	07:18 p.m.	0	0

Readings were 0 percent opacity during all periods of observation.

SUMMARY OF VISIBLE EMISSIONS

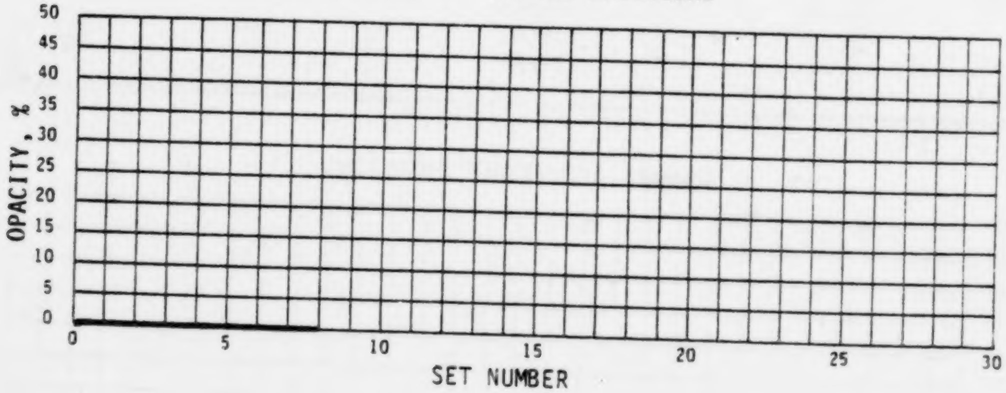


TABLE C-156. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/30/81
Type of plant	Flame attenuation
Distance from observer to discharge point	100 ft
Location of discharge	North forming stack
Height of observation point	30 ft above stack top
Height of point of discharge	80 ft
Direction of observer from discharge point	NE
Description of background	Substation
Description of sky	Overcast
Wind direction	S
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	60 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:31 a.m.	11:36 a.m.	5	5
2	11:46	11:51	5	5
3	12:00 p.m.	12:05 p.m.	10	8
4	12:14	12:19	10	10
5	12:31	12:36	10	10
6	12:45	12:50	10	10
7	01:13	01:18	10	10
8	01:36	01:41	10	10
9	01:51	01:56	10	10

SUMMARY OF VISIBLE EMISSIONS

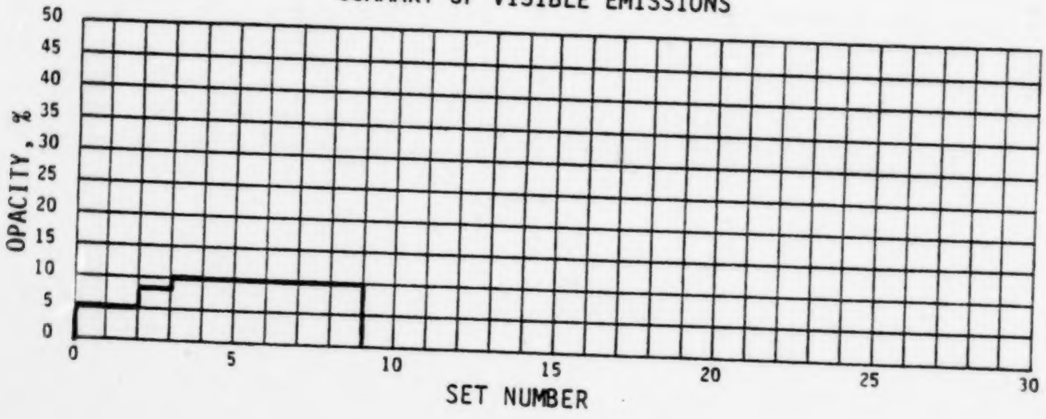


TABLE C-157. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/30/81
Type of plant	Flame attenuation
Distance from observer to discharge point	100 ft
Location of discharge	South forming stack
Height of observation point	30 ft above stack top
Height of point of discharge	80 ft
Direction of observer from discharge point	NE
Description of background	Stack
Description of sky	Overcast
Wind direction	S
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	54 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	11:39 a.m.	11:44 a.m.	5	5
2	11:52	11:57	5	5
3	12:07 p.m.	12:12 p.m.	10	9
4	12:22	12:27	10	10
5	12:37	12:42	10	10
6	12:53	12:58	10	10
7	01:52	01:57	5	5
8	02:07	02:12	5	5
9	02:20	02:25	10	10

SUMMARY OF VISIBLE EMISSIONS

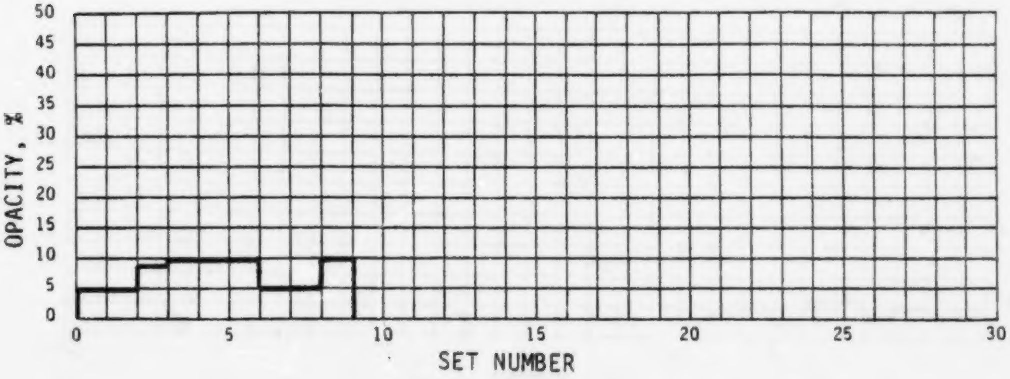


TABLE C-158. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/30/81
Type of plant	Flame attenuation
Distance from observer to discharge point	75 ft
Location of discharge	East curing stack
Height of observation point	Ground level
Height of point of discharge	30 ft
Direction of observer from discharge point	NE
Description of background	Brown and blue stack
Description of sky	100% clouds
Wind direction	SSW
Wind velocity	10 mph
Color of plume	Light blue
Duration of observation	78 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:12 a.m.	11:17 a.m.	10	4
2	11:25	11:30	5	4
3	11:38	11:43	5	5
4	11:52	11:57	10	4
5	12:05 p.m.	12:10 p.m.	10	6
6	12:18	12:23	10	6
7	12:31	12:36	10	2
8	12:43	12:48	10	5
9	12:56	01:01	5	4
10	01:08	01:13	5	3
11	01:20	01:25	10	5
12	01:46	01:51	10	10
13	01:59	02:04	10	10

SUMMARY OF VISIBLE EMISSIONS

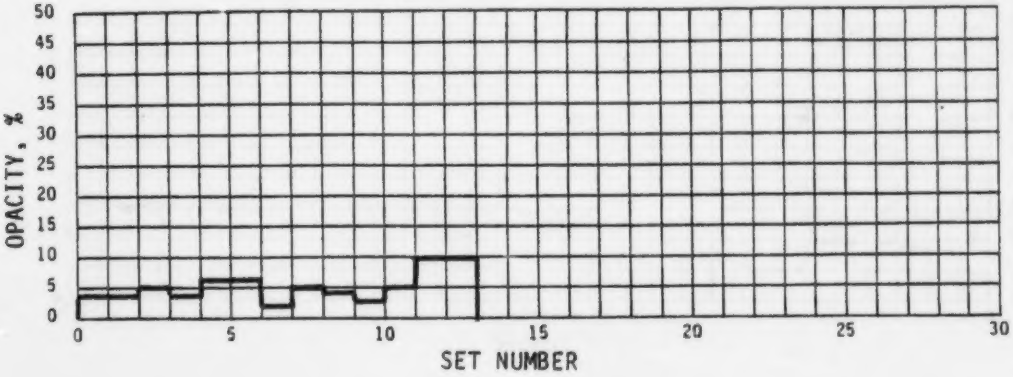


TABLE C-159. SUMMARY OF VISIBLE EMISSIONS--LINE K

Date	05/30/81
Type of plant	Flame attenuation
Distance from observer to discharge point	60 ft
Location of discharge	West curing stack
Height of observation point	15 ft
Height of point of discharge	30 ft
Direction of observer from discharge point	SE
Description of background	Brown stack
Description of sky	Overcast
Wind direction	S to N
Wind velocity	5 mph
Color of plume	White-gray
Duration of observation	84 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	11:15 a.m.	11:20 a.m.	10	10
2	11:21	11:26	10	10
3	11:27	11:32	10	2
4	11:33	11:38	0	0
5	11:39	11:44	0	0
6	11:45	11:50	0	0
7	11:51	11:56	0	0
8	11:57	12:02	5	4
9	12:03	12:08	5	5
10	12:09	12:14	5	5
11	12:15	12:20	5	5
12	12:21	12:26	5	5
13	12:27	12:32	5	5
14	12:33	12:38	5	5

SUMMARY OF VISIBLE EMISSIONS

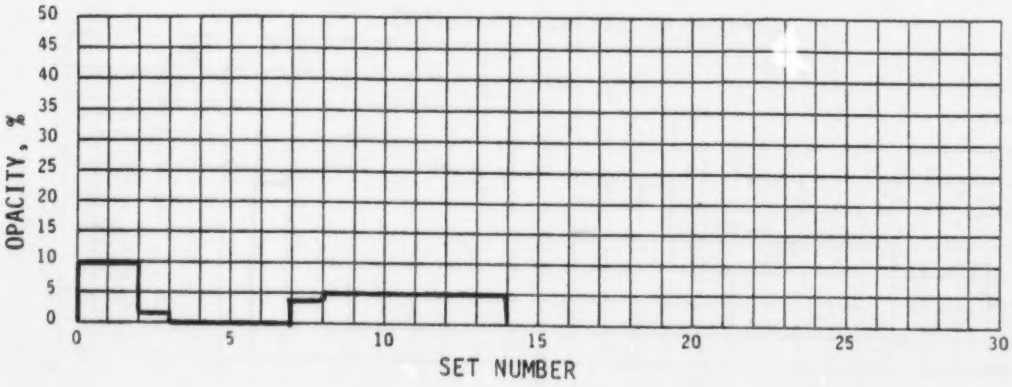


TABLE C-160. SUMMARY OF VISIBLE EMISSIONS--LINE L

Date	09/28/82
Type of plant	Rotary spin
Distance from observer to discharge point	200 ft
Location of discharge	Common scrubber stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	S
Description of background	Sky
Description of sky	Clear
Wind direction	Not reported
Wind velocity	0-5 mph
Color of plume	White (steam)
Duration of observation	144 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:55 a.m.	10:00 a.m.	20	11
2	10:01	10:06	25	17
3	10:07	10:14	25	15
4	10:15	10:20	25	16
5	10:21	10:26	25	19
6	10:27	10:32	25	19
7	10:33	10:39	25	19
8	10:40	10:45	25	19
9	10:46	10:51	25	22
10	10:52	11:01	30	23
11	11:02	11:07	30	26
12	11:08	11:13	35	28
13	11:14	11:19	35	26
14	11:20	11:25	35	30
15	11:26	11:31	35	29
16	11:32	11:37	35	29
17	11:38	11:43	40	29
18	11:44	11:49	35	30
19	11:50	11:55	35	31
20	11:56 a.m.	12:06 p.m.	35	29
21	12:07	12:12	35	29
22	12:13	12:18	35	30
23	12:19	12:24	35	29
24	12:25	12:30	35	27

SUMMARY OF VISIBLE EMISSIONS

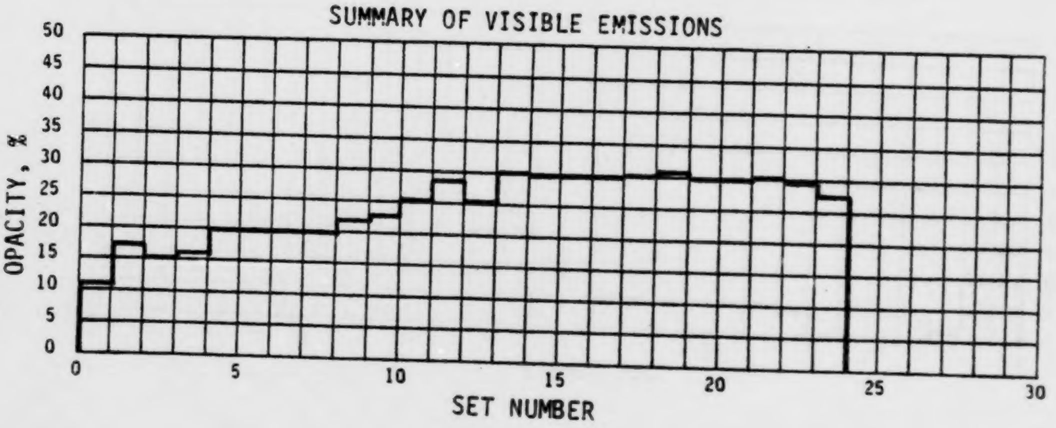


TABLE C-161. SUMMARY OF VISIBLE EMISSIONS--LINE L

Date	09/28/82
Type of plant	Rotary spin
Distance from observer to discharge point	200 ft
Location of discharge	Common scrubber stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	S
Description of background	Blue sky
Description of sky	Broken clouds
Wind direction	Not applicable
Wind velocity	Zero
Color of plume	Not reported
Duration of observation	96 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	02:13 p.m.	02:18 p.m.	25	18
2	02:19	02:24	20	17
3	02:25	02:30	30	20
4	02:31	02:36	30	20
5	02:37	02:42	30	24
6	02:43	02:48	25	21
7	02:49	02:54	30	21
8	02:55	03:00	25	21
9	03:01	03:06	30	25
10	03:07	03:24	25	23
11	03:25	03:30	25	21
12	03:31	03:36	30	24
13	03:37	03:42	30	24
14	03:43	03:48	30	26
15	03:49	03:54	25	23
16	03:55	04:00	25	21

SUMMARY OF VISIBLE EMISSIONS

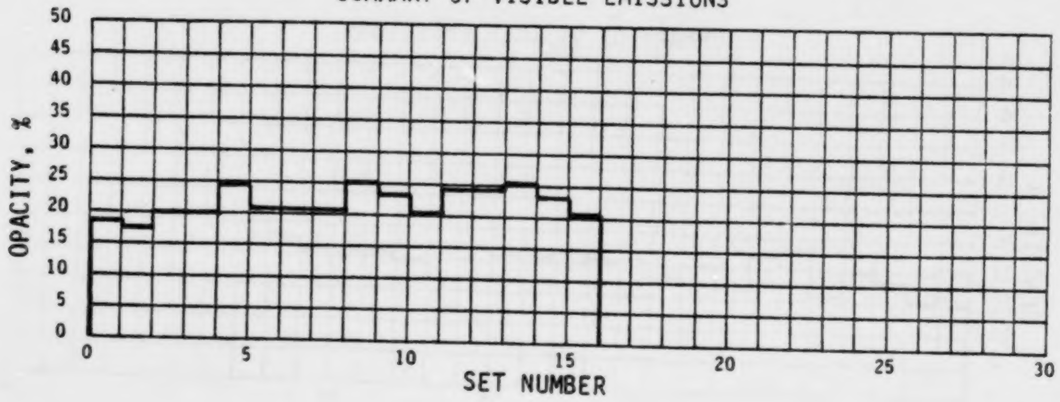


TABLE C-162. SUMMARY OF VISIBLE EMISSIONS--LINE L

Date	09/29/82
Type of plant	Rotary spin
Distance from observer to discharge point	250 ft
Location of discharge	Common scrubber stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	SSE
Description of background	Sky
Description of sky	Clear
Wind direction	N to S
Wind velocity	3-5 mph
Color of plume	White (steam)
Duration of observation	132 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	09:10 a.m.	09:15 a.m.	30	21
2	09:16	09:21	30	15
3	09:22	09:27	25	18
4	09:28	09:33	25	20
5	09:34	09:39	25	16
6	09:40	09:45	35	23
7	09:46	09:51	35	22
8	09:52	09:57	25	17
9	09:58	10:03	35	20
10	10:04	10:09	35	18
11	10:12	10:17	40	21
12	10:18	10:23	35	21
13	10:24	10:29	30	22
14	10:30	10:35	40	21
15	10:36	10:41	30	21
16	10:42	10:47	40	22
17	10:48	10:53	30	22
18	10:54	10:59	30	19
19	11:00	11:05	30	21
20	11:06	11:11	30	21
21	11:14	11:19	30	21
22	11:20	11:25	30	23

SUMMARY OF VISIBLE EMISSIONS

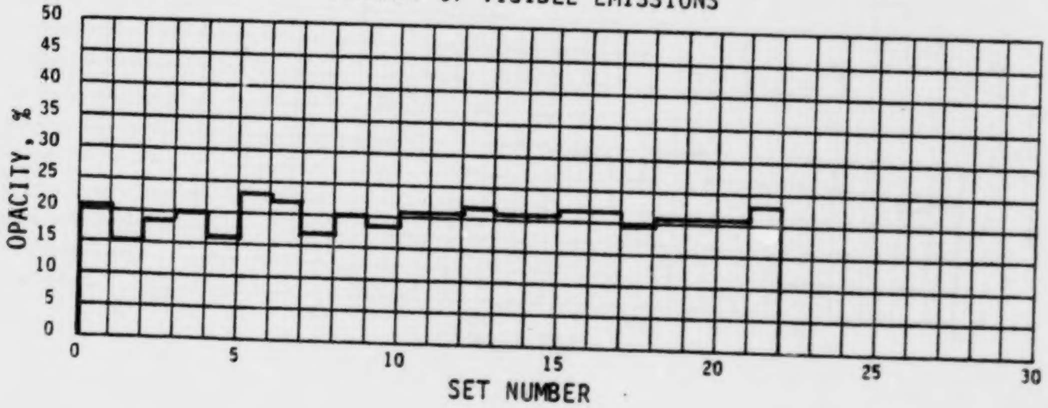


TABLE C-163. SUMMARY OF VISIBLE EMISSIONS--LINE L

Date	09/29/82
Type of plant	Rotary spin
Distance from observer to discharge point	200 ft
Location of discharge	Common scrubber stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	SE
Description of background	Sky
Description of sky	Broken clouds
Wind direction	SE to NW
Wind velocity	0-5 mph
Color of plume	White
Duration of observation	84 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	01:25 p.m.	01:30 p.m.	35	23
2	01:31	01:36	35	27
3	01:37	01:42	30	23
4	01:43	01:48	45	31
5	01:49	01:55	35	29
6	01:56	02:02	35	25
7	02:03	02:08	35	26
8	02:09	02:14	30	25
9	02:15	02:20	35	20
10	02:21	02:30	40	25
11	02:31	02:36	30	22
12	02:37	02:42	35	21
13	02:43	02:48	40	25
14	02:49	02:54	30	20

SUMMARY OF VISIBLE EMISSIONS

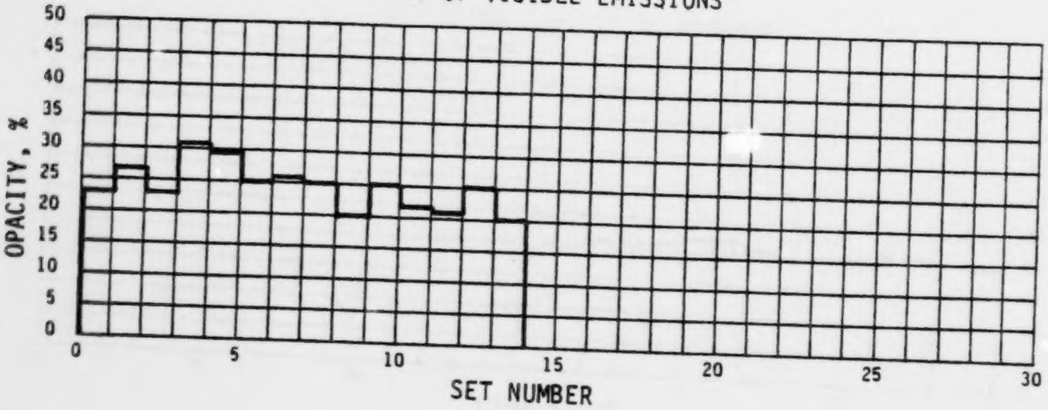


TABLE C-164. SUMMARY OF VISIBLE EMISSIONS--LINE L

Date	09/30/82
Type of plant	Rotary spin
Distance from observer to discharge point	200 ft
Location of discharge	Common scrubber stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	ESE
Description of background	Sky
Description of sky	Clear
Wind direction	N to S
Wind velocity	0-5 mph
Color of plume	White (steam)
Duration of observation	90 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time Start	Time End	Opacity Maximum in 6 min	Opacity 6-min average
1	09:05 a.m.	09:10 a.m.	35	19
2	09:11	09:16	35	24
3	09:17	09:22	30	21
4	09:23	09:28	35	21
5	09:29	09:34	30	20
6	09:35	09:41	30	20
7	09:42	09:47	30	20
8	09:48	09:53	25	21
9	09:54	09:59	30	22
10	10:00	10:05	25	22
11	10:06	10:11	25	21
12	10:12	10:17	30	21
13	10:18	10:23	30	21
14	10:24	10:29	25	20
15	10:30	10:35	30	24

SUMMARY OF VISIBLE EMISSIONS

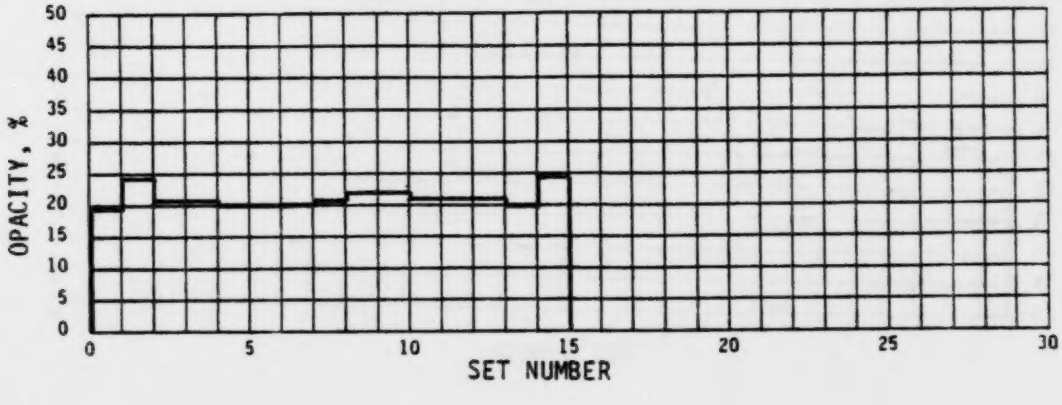


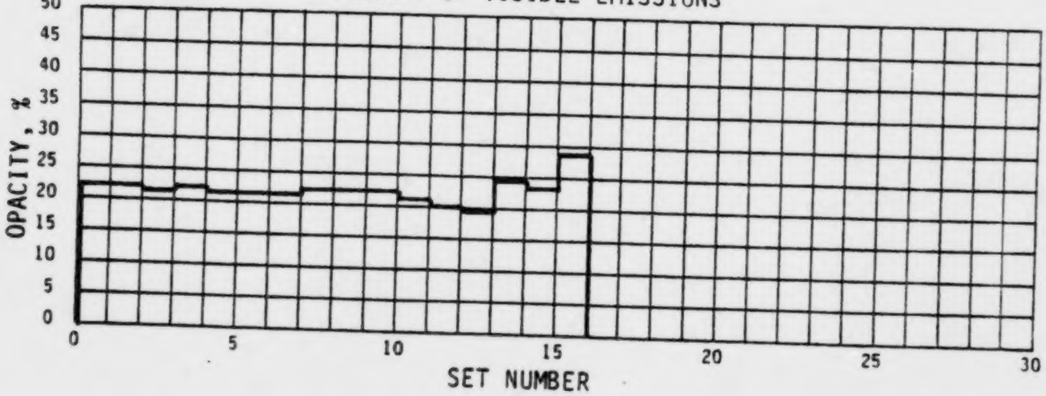
TABLE C-165. SUMMARY OF VISIBLE EMISSIONS--LINE L

Date	09/30/82
Type of plant	Rotary spin
Distance from observer to discharge point	200 ft
Location of discharge	Common scrubber stack
Height of observation point	Ground level
Height of point of discharge	80 ft
Direction of observer from discharge point	ESE
Description of background	Sky
Description of sky	Broken clouds
Wind direction	NE to SW
Wind velocity	5-7 mph
Color of plume	White (steam)
Duration of observation	96 min

SUMMARY OF AVERAGE OPACITY

Set No.	Time		Opacity	
	Start	End	Maximum in 6 min	6-min average
1	12:00 p.m.	12:05 p.m.	30	22
2	12:06	12:11	30	22
3	12:12	12:17	25	21
4	12:18	12:23	30	22
5	12:24	12:30	25	21
6	12:31	12:36	25	21
7	12:37	12:42	25	21
8	12:43	12:48	30	22
9	12:49	12:54	25	22
10	12:55	01:07	25	22
11	01:08	01:13	25	21
12	01:14	01:19	25	20
13	01:20	01:25	20	19
14	01:26	01:34	30	24
15	01:35	01:56	30	23
16	01:57	02:02	35	28

SUMMARY OF VISIBLE EMISSIONS



APPENDIX D

EMISSION MEASUREMENT METHODS

D.1 INTRODUCTION

In the manufacture of wool fiberglass insulation, solid and liquid organic and inorganic particles are generated and emitted to the atmosphere from various sources in the process. These particles consist of glass fibers, various resinous phenolic compounds, and other components of the resin. Emissions of particles were measured using EPA Method 5 sampling trains and procedures modified for the analysis of pollutants other than particulate matter.

The modifications were made as a result of laboratory and field evaluations of sampling and analytical procedures for the determination of the emissions of particulate matter, total organic carbon, phenol and phenolic compounds, and formaldehyde. Procedures for sample collection were essentially the same as specified Method 5, but sample recovery and analyses were modified. For the method development and standards development testing, portions of the various liquid samples were analyzed for phenol and phenolic compounds, formaldehyde, total organic carbon (TOC), chloroform/ether extractable compounds, as well as for particulate matter by standard EPA Method 5 gravimetric procedures.

Several sample collection procedures and analytical methods were evaluated by literature review and by laboratory and field tests prior to the standards development testing. The results of these investigations led to selection of the analytical and sampling procedures for the standards development testing.

A total of 53 separate locations on 11 process lines at six wool fiberglass manufacturing plants were sampled during the standards development testing. This testing included sampling controlled and uncontrolled sources and inlets and outlets of emission control devices. Opacity observations were made where appropriate. This Appendix describes the rationale for selection of the methods used, the sampling train, the sample collection procedures, and the analytical methods used to generate the test data.

D.2 SELECTION OF TESTING AND ANALYTICAL METHODS

D.2.1 Preliminary Review

The EPA investigated several candidate sampling and analytical procedures for sampling emissions from wool fiberglass manufacturing operations. The pollutants of interest were particulate matter, phenol, and formaldehyde. The evaluation consisted of reviewing data and methods which had been used to sample and analyze fiberglass plant emissions and of reviewing other methods which might be applicable. The conclusion of the preliminary reviews was that the best method of sampling particulate matter, phenol, and formaldehyde simultaneously was EPA Method 5 with 0.1 N NaOH in the impingers. It was concluded that the possibility of phenol and formaldehyde sorption by the filtered particulate matter should be investigated and that the probe and filter assembly should be heated to prevent the condensation of phenol. It was also concluded that, during initial testing, the impinger contents should be analyzed for Total Organic Carbon (TOC) by standard procedures to determine if more organic matter were present in the gas streams than could be accounted for by phenol and formaldehyde and, if so, whether the organic matter passed through the filter and collected in the impingers.

It was necessary to analyze the impinger catch for both phenol and formaldehyde. Analysis for formaldehyde by the chromatropic acid method (Reference 3) seemed to be the best procedure but literature reports indicated possible interferences from phenol.[3] Other methods were available for the analysis of formaldehyde if required; the most promising of which was the Imperial Chemical Industries (ICI) method.[4] Both of these methods were evaluated in the laboratory to determine the most suitable method prior to the initiation of field sampling.

The recommended method of analysis for phenol was Method 510 as specified in Standard Methods.[5] This method was expected to be relatively free from interferences, and its sensitivity was adequate.

The laboratory evaluation work was conducted concurrently with preparations for field testing because no new or exotic equipment was needed for the sampling. In the interest of simplicity, standard EPA Method 5 trains were used for the majority of the field evaluations. Midget impinger trains could have been substituted for the collection of phenol and formaldehyde had it been found necessary to sample using two different trains.

D.2.2 Laboratory Evaluation of Analytical Methods

The analytical procedures were evaluated in the lab prior to the field testing program. The goals of this evaluation were to:

1. Verify detection limits of the methods;

2. Generate precision and accuracy data;
3. Determine the nature and magnitude of interferences;
4. Determine sample stability over time;
5. Evaluate possible interference removal techniques; and
6. Evaluate phenol and formaldehyde relationships to TOC.

The lab evaluation was conducted by preparing a number of samples spanning the range of concentration expected to result from field sampling. Interferences were evaluated by analyzing simulated field samples containing known but varying amounts of both phenol and formaldehyde.

D.2.2.1 Phenol

The method of analysis for phenol was a spectrophotometric procedure using 4-aminoantipyrine. The working range of the method was found to be 0.5 to 5.0 mg/l with a 1 cm photometer cell. Using 4 cm cells, the detection limit can be lowered to 0.2 mg/l. Formaldehyde interference was evaluated and was not found to occur over the range of expected concentrations. Total organic carbon analyses of phenol samples showed a linear relationship between measured TOC and phenol concentration, but the measured TOC values were higher than the theoretical values.

D.2.2.2 Formaldehyde

The recommended analytical procedure for formaldehyde (NIOSH Method P&CAM 125) was the chromotropic acid/spectrophotometric method. The method was recommended because of its simplicity and sensitivity. Phenol interference was known to occur, but the extent of the interference and whether the interference could be accounted for or removed were not known.

Analysis of formaldehyde samples containing varying known amounts of phenol showed a definite phenol interference. At phenol to formaldehyde ratios of greater than 10:1 a negative interference occurred and increased with increasing phenol/formaldehyde ratio. At approximately 30:1, the interference becomes complete with spectrophotometer absorbance of samples approaching zero.

Bromination of the sample, mentioned in other chromotropic acid descriptions as a technique for removing phenol interferences, met with limited success, and then only at phenol concentrations less than 20 mg/l. A bromine (Br_2/Br) solution was added to samples containing from 5 to 200 mg/l phenol, and sodium metabisulfite was added to destroy excess Br_2. This procedure might be developed, but additional method development work was not considered to be within the scope of work.

Another method, the phenylhydrazine colorimetric procedure (Section 6.3.2, Analysis of Organic Air Pollutants, W. Leithe), was then evaluated. Formaldehyde, in the presence of hydrochloric acid (HCl), will react with phenylhydrazine hydrochloride to produce the phenylhydrazone of formaldehyde and yield a pinkish colored solution. Potassium ferricyanide is also used and will react with phenol in an alkaline solution and produce a positive interferring color. Acidification of the sample prior to adding the ferricyanide prevents phenol interference at phenol concentrations up to more than 300 mg/l. This method has a working range of 1.0 to 10.0 mg/l formaldehyde using 1 cm spectrophotometer cells.

Total organic carbon analysis of formaldehyde gave results similar to those for phenol, i.e., a linear relationship but measured values

TABLE D.1

NUMBER OF RUNS

Comparison	Source			Total
	A	B	C	
Filter	3	3	0	6
vs.				
No Filter	3	3	0	6
120°C Filter	3	3	1	7
vs.				
160°C Filter	3	3	1	7
120°C Filter	2	3	1	6
vs.				
70°C Filter	2	3	1	6
Total	16	18	4	38

were higher than theoretical. No decay was found in samples refrigerated for up to 20 days.

D.2.2.3 Field Evaluation Program

The field evaluation program consisted of a total of 38 individual runs, yielding 19 sets of paired samples. Table D.1 summarizes the sample collection matrix. The sources were selected to represent a controlled emission and two types of uncontrolled discharges.

The sample collection procedure employed EPA Method 5 type sampling trains. Sampling procedures followed those of Method 5 with the following exceptions:

1. All sampling was done at a single point. A velocity traverse was performed and the samples collected at a point of average velocity. Velocities in the stack were relatively uniform across the traverses.
2. The filter was omitted from one train in one series of comparison runs.
3. Impingers 1 and 2 each contained 100 ml of 0.1 N NaOH.

Sampling trains were leak checked before and after each run, and leakage rates were noted on the field data sheets. Initially, stack and sample train data were recorded every 5 minutes, and appropriate adjustments were made. Operating conditions were stable enough that 10-minute data readings were found to be sufficient.

Some aspects of the test method were evaluated in the field. Filter blinding due to condensed organic material on the filter did not occur on any of the tested sources, and there was no evidence of such a potential. However, the maximum weight gain on the filters was only 80 mg.

Sampling of wet gas streams was of concern. The tested sources, while saturated and containing some water droplets, had stack temperatures of about 38°C (100°F). The heated probe and filter box prevented any condensation of water on the filter.

D.2.2.4 Analysis Results and Conclusions

As expected, filtration temperature affected the amount of material retained on the filter. At higher temperatures, less material was retained on the filter. The effect of temperature was more apparent on the uncontrolled sources.

Phenol, as determined by the 4-aminoantipyrine method, was found in the front half (probe rinse and filter) in all the runs. This was not expected. Filtration temperature appeared to affect the amount of phenol deposited in the front half in the same way as had been observed with particulate matter.

Because phenol has sufficient vapor pressure at the sample temperatures and concentrations to remain gaseous, the measured phenol on the filter could have resulted from chemical reaction or from other phenolic compounds to which the analytical method responded. To confirm the presence of phenol (C_6H_5OH) on the filter, several front half samples (those containing more than 10 percent of the total observed phenol) were subjected to gas chromatographic analysis. The front half samples contained no detectable free phenol.

The 4-aminoantipyrine method was known to respond to substituted phenols, but it was not known before the field test whether any would be present. Since phenolic compounds other than phenol were present on the filter, several impinger solutions were analyzed by the GC technique. Detailed organic analyses were beyond the scope of work and were not attempted, but the method employed was sufficiently sensitive for these confirmations. On the average, only 46 percent of the phenol measured by the 4-aminoantipyrine method was in fact free phenol. The remainder of the phenol measured by the colorimetric method was apparently a mixture of substituted phenolic compounds which reacted in the analyte to form dyes similar to that formed by phenol. The absorbance of these reaction products depends on what specific compounds are present. At the same concentrations, different phenolic compounds will yield different results. Thus, samples containing the same total concentration of phenolic compounds will yield different results when analyzed by the 4-aminoantipyrine method and the results will depend on the relative proportions of the different compounds present in the sample.

As mentioned, the data showed that less phenolics were measured in the front half at higher temperatures. The data suggested that either phenolic compounds were being liberated from the filter residue by exposure to higher temperature or, more likely, that more condensible phenolic matter passed through the filter to be condensed in the impingers.

The data showed that the 4-aminoantipyrine-spectrophotometric method measures phenolic compounds other than phenol in the emissions from process sources in wool fiberglass plants. The method is reproducible. Replicate analyses of 40 samples demonstrated a precision of ± 2 percent.

Problems with the formaldehyde analyses were similar to those encountered with phenol. In addition, potential problems with sample stability were observed. The temperature effects observed for particulate and phenol concentration were not as pronounced with formaldehyde.

Evaluation of the front half/back half catches of formaldehyde samples provide some unexpected results. Less formaldehyde was measured in the stack gas when the filter was removed than when the a filter was in place. The sampling train without a filter measured, on the average, about 58 percent of the formaldehyde measured by the train operated with a 120°C (248°F) filter. Formaldehyde is too volatile to be collected as a condensed particle on a filter. Formaldehyde was measured in filter extracts and could have been sorbed onto the particulate matter, or it could have resulted from a reaction initiated by the extraction process or from a positive interference in the analytical method. The method is reportedly specific for formaldehyde so an interference is unlikely. However, the low concentrations measured (1-8 ppm) and relatively small differences in the comparisons made it difficult to draw any firm conclusion.

Replicate analyses of samples, field and laboratory spikes, and controls were also conducted. The formaldehyde replicates did not show the degree of reproducibility that the phenol replicates did. Recovery of field and laboratory spikes was also poor. Individual replicates varied as much as 24 percent from the average, and field spike recoveries ranged from 21 to 180 percent. Lab spike recoveries ranged from 27 to 97 percent. The low concentration increased the relative importance of analytical variations. Control samples showed good reproducibility which (in conjunction with poor spike recoveries) indicated that the nature of the samples was changing as they aged.

The data suggested that little of the measured formaldehyde deposited in the probe (less than 10 percent) and that the effect of the filter temperature, if there was any effect or trend, followed that of the particulate matter and phenol (i.e., at higher temperatures, less formaldehyde was found on the filter while at the lower temperatures, more formaldehyde was measured on the filter). As previously mentioned, formaldehyde is too volatile to condense on the filter at the filtration temperatures used, so the observed differences stemmed either from a reaction occurring on the filter or from sample instability.

A number of samples were analyzed for TOC. The data indicated that measured phenolics and formaldehyde accounted for only about 2/3 of the organic carbon in the impingers. While the TOC is not the total mass of condensable organic matter collected, it is representative of the total condensable matter collected in the impingers. The non-carbon component of the condensable (hydrogen, oxygen, nitrogen, etc.) should be quite constant, and the data indicated close agreement between the simultaneously collected samples.

The TOC analyses also indicated that the differences in measured particulate matter observed as a result of filter temperature variations are accounted for in the impinger catch and further that the differences observed for phenol and formaldehyde may well be the result of reactions among the various organics present. The total material collected in the paired trains was approximately equal while the relative amounts and types collected at different locations in the train were not.

The data showed that the quantity of condensable organic matter is often greater than the quantity of filtered particulate matter. Even if the phenol and formaldehyde portion of this organic carbon were neglected, substantial amounts of non-phenolic non-formaldehyde organic compounds were present. Depending on the source and filter temperature, the amount of organic matter passing through the filter that was not phenol or formaldehyde ranged from five times the particulate matter collected in the front half to one fifth of the front half catch.

D.3 SAMPLING TRAIN

The equipment used for standards development sample collection was a modified EPA Reference Method 5 train (40 CFR Part 60, Appendix A).

D.3.1 Measurement of Filtration Temperature

The physical state of organic matter is a function of temperature, pressure, and concentration and in this sampling program temperature is the most critical factor. The discharge temperature of the exhaust gas streams tested ranged from slightly above ambient to approximately 700°C (1300°F), and many of the lower temperature gas streams, both controlled and uncontrolled, contained entrained water droplets. Therefore, it was necessary to keep the sample gas temperature above 105°C (220°F).

Filtration temperature was measured by insertion of a temperature measuring device into the sample gas stream directly behind the filter support frit. Measuring the temperature of the filtered gas obviates the need for calibration of filter compartment thermocouples and heaters and ensures that the sample gas stream is maintained at the selected temperature. Temperature regulation can be accomplished manually or with temperature controllers but in either case, the temperature being controlled is filtration temperature, not compartment or surrounding air temperature.

D.3.2 Sampling Lines

Phenol has an affinity for stainless steel so glass sample lines were necessary to minimize phenol loss to the probe walls. This applies to the impinger train as well as the probe liner as the majority of the phenol and phenolic compounds are collected in the impingers.

D.3.3 Impinger Solution

The first two impingers were filled with 100 ml each of a dilute caustic solution (0.1 N NaOH) for phenol and formaldehyde absorption. The initial review of sampling methods revealed that phenol, while soluble in water, is more so in caustic, and most sampling techniques involving collection of phenol in impingers use dilute caustic absorbing medium. Analysis of samples collected with three wet impingers in series showed typically less than 1 percent of the total phenol and formaldehyde in the third impinger. The collection efficiency of a single impinger is estimated to be about 90 percent.

D.4 SAMPLE COLLECTION

The sampling procedures described in Method 5 were used for sample collection during the standards development portion of the testing. Multiple point isokinetic sampling was done at sampling points located according to EPA Methods 1 and 2 wherever existing ductwork permitted. Sample gas molecular weight was determined by Orsat analysis of integrated bag samples taken simultaneously with the emission testing.

In some cases, particularly at control device inlets and in gas manifolds, it was not possible to locate sampling ports the requisite distance from flow disturbances or to sample the required number of points in the appropriate matrix. In these cases, sampling was conducted in locations and in point matrices as close as possible to those specified in Methods 1 and 2. Despite the nearness of some sampling locations to flow disturbances, velocity profiles were generally uniform and results are considered to be representative.

The test program usually involved testing several process streams (usually 4, 5, or 6) simultaneously to quantify the emissions from various parts of the manufacturing operation. In some cases, it was necessary to determine emission rates by difference because some process effluents could not be sampled directly. In these cases, a combination gas stream and all but one of the confluent substreams were sampled simultaneously to allow calculation of the emission contribution from the untestable gas stream.

Some modifications to the sampling train were necessary at certain test locations. At several locations the need to perform a vertical traverse in a horizontal duct required a 90° glass adapter between the probe liner and the filter holder. The presence of entrained water droplets in a fairly high velocity gas stream plugged the impact side of the type S pitot tube at two sites. At these locations, velocity head was measured using a continuous purge/differential pressure transducer flow meter. One source had a gas temperature of 700°C (1290°F) and required an air cooled probe sheath to cool the sample to 120°C (248°F) at the filter.

A cyclone precollector was required for the removal of entrained droplets at some locations, however none of these locations discharged directly to the atmosphere. A low range manometer (minimum division 0.005 in., 0.13 mm) was required in a limited number of cases.

D.5 SAMPLE RECOVERY

The sample recovery techniques of Method 5 were employed with modifications necessary to obtain samples suitable for subsequent analysis. In order to analyze the front half catch for phenol and formaldehyde, it was necessary to first rinse the front half components with distilled water. Any remaining particulate matter was then recovered with acetone rinsing and brushing as required by Method 5. The back half sample recovery was performed using 0.1 N NaOH as the rinse solution. These procedures are described below.

At the conclusion of the test run (after the final leak check), the probe was disconnected from the rest of the train and capped. Filter and impinger inlets and outlets were also capped, and the probe and impinger box were returned to the sample recovery area for cleanup. All front half components were rinsed three times with distilled water to remove water soluble particles. Probe liner rinsing was accomplished in a manner similar to that specified by Method 5 except both ends were capped and the probe rotated axially and oscillated longitudinally to ensure wetting of all internal surfaces. The probe was not brushed during water rinsing.

A minimum of three acetone rinsings and brushings followed the water rinses.

The filter was removed from the glass housing and placed in a correspondingly numbered glass petri dish. The front half of the filter holder was first rinsed with distilled water, and the rinse was placed into the appropriate probe wash container. The filter holder was then brushed and rinsed with acetone into the appropriate probe wash container. The contents of the first three impingers were transferred to a graduated cylinder and the volume measured and noted. The impingers, back half of the filter holder, and connecting glassware were rinsed with 0.1 N NaOH into the graduated cylinder. The final volume was then measured and noted. The contents of the graduated cylinder were then poured into a sample bottle. All glass sample containers were labeled, identifying source, date of sampling, type of sample (i.e., front half probe rinse, back half NaOH), and run number. Silica gel from the fourth impinger was transferred to the original plastic bottle(s) and weighed on a triple beam balance to the nearest 0.1 g. Sample bottles were narrow mouth glass bottles with Teflon lined caps. Liquid levels were marked on the bottles and the caps taped to prevent sample loss.

D.6 ANALYSIS

The following sections describe the sample handling and analytical procedures used for the standards development testing. As previously discussed, literature review, laboratory evaluation, and field evaluation

evaluation were conducted to develop these sampling and analytical techniques for the wool fiberglass manufacturing industry.

Each run generated one water rinse of the front half, one acetone front half rinse, one or more filters, and one impinger and rinse sample. All liquid samples (except acetone rinses) were analyzed for formaldehyde on-site at the field laboratory. Analysis for formaldehyde was commenced immediately after collection of samples to minimize potential degradation of collected formaldehyde. At the conclusion of the testing, all samples were taken by test personnel to the laboratory for analysis. Analytical methods and laboratory procedures are discussed below.

D.6.1 Analysis for Particulate Matter

D.6.1.1 Probe Rinse - Water

Distilled water was used for all rinses and blanks were run to determine a residue concentration. The volume of the sample was measured in graduated cylinders. Aliquots were removed for phenol and formaldehyde analysis. The remaining volume was measured and transferred to tared and numbered beakers and evaporated to dryness at ambient pressure and temperature under a laboratory hood. The beakers were then desiccated to constant weight and results were reported to the nearest 0.1 mg.

Constant weight for tare weighings is defined as a difference of no more than 0.5 mg between two consecutive weighings with at least six hours of desiccation between weighings. For gross weights, the allowable difference is no more than 0.5 mg or no more than 1 percent of the difference between gross and tare weights if the 0.5 mg criterion cannot be met. The averages of the two successive weights are used in the calculations.

D.6.1.2 Probe Rinse - Acetone

Reagent grade acetone was used for rinses and the procedures for determining the residue were the same as the water rinses except that the total sample was evaporated because aliquots were not needed for other analysis.

D.6.1.3 Filters

Prior to sampling, filters were labeled on the back side near the edge, and visually checked for flaws, irregularities, or pinhole leaks. A series of glass petri dishes were marked with the same numbers as the filters and the respective filters placed in the dishes. Each filter/ petri dish was thereafter handled as a unit.

The filter/petri dish sets were desiccated at 20°C ± 5°C (68°F ± 10°F) and ambient pressure for at least 24 hours and weighed at six-hour intervals to a constant weight as described previously. After sample collection, the filters were desiccated and weighed in the same manner as above and results reported to the nearest 0.1 mg. Filters and dishes were handled only with forceps or with latex gloves.

After final weighing, the filters were cut into quarters and the quarters were placed in a sample bottle containing 130 ml 0.1 N NaOH. The bottles were then vigorously shaken, and the contents were allowed to settle overnight. After settling, aliquots were withdrawn and analyses for phenol and formaldehyde were conducted, as described below.

D.6.1.4 Impinger Solutions

The volume of the collected sample was again measured, and aliquots were removed for phenol, formaldehyde, and TOC analyses, as were 200 ml aliquots for chloroform/ether extractions. Analytical procedures are described in the following section.

D.6.1.4.1 Extractable Organic Compounds (Chloroform/Ether Extraction)

A 200 ml aliquot of impinger sample was placed in a separatory funnel and acidified with 6 N hydrochloric acid to a pH of approximately 2. Twenty-five ml of reagent grade chloroform were added to the sample, and the sample and chloroform mixture was shaken vigorously for 60 seconds. The mixture was allowed to settle, and after the chloroform had separated into a distinct layer, it was filtered through a layer of sodium sulfate (to remove any water) into a previously numbered and tared glass beaker. This process was repeated twice more with 25 ml of chloroform each time. Then, the sodium sulfate was rinsed with 10 ml chloroform, and the rinse was added to the tared beaker.

The 200 ml sample aliquot was then treated with three 25 ml extractions of reagent grade diethyl ether, in a similar fashion to the chloroform extractions. Each 25 ml of ether was added to the tared beaker containing the chloroform after being filtered through sodium sulfate. Finally, the sodium sulfate was rinsed with 10 ml ether, and the rinse was added to the beaker.

The chloroform/ether mixture contained in the tared beaker was evaporated at laboratory temperature to dryness under a laboratory hood. After evaporation, the beaker was desiccated at 20°C ± 5°C (68°F ± 10°) to a constant weight and results were reported to the nearest 0.1 mg.

D.6.1.4.2 Total Organic Carbon

A 25 ml aliquot was placed in a beaker and acidified to a pH of 2 to 3 and warmed at 50°C (120°F) for 15 minutes to remove the inorganic carbon (dissolved CO_2 and carbonates). A 50 microliter portion was injected into the total carbon converter of a Beckman TOC analyzer, and another was injected into the inorganic carbon converter. Total organic carbon is determined by the difference in peak height between the total carbon and inorganic carbon. A total carbon standard (potassium acid phthalate) and an inorganic carbon standard (sodium carbonate and bicarbonate) were used for calibration of instrument response. A detailed description of the analytical procedure follows in Section D.7.1.

D.6.2 Phenol Analysis

Phenol analyses were done by two methods -- a gas chromatographic method and wet chemical colorimetric method. The wet chemical procedure responds to substituted phenolic compounds such as o-cresol ($CH_3C_6H_4OH$) as well as phenol (C_6H_5OH), but the response for these other compounds is less than the response for phenol and is dependent on the specific compound involved. The samples were also analyzed on a gas chromatograph with appropriate columns for quantification of free phenol. These procedures are described in the following sections. Detailed descriptions of the methods follow in Sections D.7.2 and D.7.3.

D.6.2.1 Phenol Analysis (4-Aminoantipyrine Method)

Depending on the expected concentration and the turbidity of the sample, either a 50 ml aliquot of sample, or a lesser sample volume diluted to 50 ml, was placed in a beaker and 1.0 ml of 5 percent ammonium chloride (NH_4Cl) was added. The pH was adjusted to 10.0 ± 0.2 with 6 N HCl, and 1.0 ml of a 2 percent solution of 4-aminoantipyrine was added and mixed well. This was followed by addition of 1.0 ml of an 8 percent solution of potassium ferricyanide. After 15 minutes, the absorbance of the resultant colored solution was measured in the spectrophotometer at a wavelength of 5[illegible] nm in a 1 cm cuvette.

A blank and series of standard solutions which were made up in 0.1 N NaOH were analyzed in the same manner. The colored dye was stable for a minimum of one hour. Standards ranged from 0.5 to 5.0 mg/l.

D.6.2.2 Phenol Analysis (Gas Chromatographic Method)

Impinger catches and a caustic wash of the filter were analyzed for free phenol by gas chromatography. A Hewlett-Packard 5830A gas chromatograph (GC) with a flame ionization detector (FID) was used to separate and measure phenol and other phenolic compounds. This GC/FID was equipped with a microprocessor which provided automatic integration of peak areas of a chromatogram. Standards of selected phenols in the range of expected concentration were run to provide elution times, relative retention, and calibration factors.

Typically, 1 microliter of sample was injected into the column and the phenolic compounds eluted at the relative retention times shown below:

1. phenol - 1.00
2. o-cresol - 2.30
3. p-cresol - 2.68
4. p-ethylphenol - 4.30
5. 2,3 dimethylphenol - 7.38

A six-foot glass column 2 mm ID was used. The column was packed with 0.1 percent SP-1000 on Carbopack C operated at 225°C (435°F). SP-1000© is a brand name (Supelco Phase) of a derivative of terephthalic acid prepared from Carbowax 20M. High purity nitrogen was used as carrier gas at a flow rate of 12 to 20 ml/min. Use of a glass column and on-column injection are necessary to minimize phenol loss to metal parts. A column containing 80/100 mesh Tenax® was also used. The Tenax column does not separate some of the substituted phenolics (i.e., m- and p-cresol) but alleviates some of the "ghosting" problems encountered with the SP-1000 packing.

D.6.3 Formaldehyde Analysis (Phenylhydrazine Method)

Depending on the expected concentration and the turbidity of the sample either a 15 ml aliquot of sample, or a lesser volume diluted to 15 ml, was placed in a 50 ml Erlenmyer flask and acidified with 1.0 ml of 6 N HCl. One ml of 5 percent potassium ferricyanide was added, and after four minutes, 4 ml of concentrated HCl were added. After a five

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minute wait, 2 ml of 1.4 percent phenylhydrazine hydrochloride were added and the sample was mixed well. The resultant phenylhydrazone of formaldehyde yielded a pinkish color and the absorbance was read at 515 nm in 1 cm cuvettes after 15 minutes. A blank and series of standards in the range of 0 to 12.0 mg/l formaldehyde were analyzed in the same manner. Section D.7.4 contains a detailed description of the procedure.

D.6.4 Visual Emissions Observations Method

Observations of visible emissions from discharges to the atmosphere were made concurrently with the emissions sampling when appropriate. These observations were made using EPA Method 9 procedures (40 CFR Part 60, Appendix A). Opacity readings were recorded every 15 seconds, except during interruptions in production or testing, or when it was necessary for observers to rest their eyes. Each observer location was selected to provide both a clear view of the emissions without interference from the sun and a line of vision approximately perpendicular to the plume direction with a good background for observation. Wind shifts at times prevented continuous observation and the data sheets so indicate. Adverse conditions were seldom serious enough to preclude making sufficient observations for each run.

D.7 DETAILED ANALYTICAL METHODS

The following sections describe the instrument procedures used for analysis for the various sample aliquots.

D.7.1 Total Organic Carbon

D.7.1.1 Principle

For the determination of total organic carbon, two analyses are performed on successive identical samples, i.e., total carbon and inorganic carbon. These two analyses are run on separate channels, or sample paths, of the analyzer. The desired quantity is the difference between the two values obtained. Both analyses are based on conversion of sample carbon into CO_2 for measurement by a non-dispersive infrared analyzer. Results of analyses register as peaks on a strip chart recorder.

The principle differences between operating parameters for the two channels involve the combustion tube packing material and temperature. In the total carbon channel, a high temperature (950°C, 1740°F) furnace heats a Hastelloy combustion tube packed with cobalt oxide-impregnated asbestos fiber. The oxygen in the carrier gas, the elevated temperature, and the catalytic effect of the packing result in oxidation of both organic and inorganic carbonaceous material to CO_2 and steam. In the inorganic carbon channel, a low temperature (150°C, 300°F) furnace heats a glass tube containing quartz chips wetted with 85 percent phosphoric acid. The acid liberates CO_2 and steam from inorganic carbonates. The operating temperature is below that required to oxidize organic matter.

D.7.1.2 Equipment

1. Sample Blender or Homogenizer - Waring type or ultrasonic
2. Magnetic Stirrer
3. Hypodermic Syringe - 0 to 100 μl capacity
4. Total Organic Carbon Analyzer - Beckman Model 915 with 215B infrared analyzer

D.7.1.3 Reagents

1. Distilled Water - prepare blank and standard solutions with carbon-free water.
2. Hydrochloric Acid, HCl, Concentrated
3. Total Carbon Stock Solution - dissolve 2.125 g dried potassium biphthalate in CO_2-free water and dilute to 1 liter in a volumetric flask. This solution contains 1000 mg/l organic carbon.
4. Inorganic Carbon Stock Solution - dissolve 4.404 gm anhydrous sodium carbonate in about 500 ml of CO_2-free water in a 1 liter volumetric flask. Add 3.497 gm anhydrous sodium bicarbonate to the flask and dilute to 1 liter with CO_2-free water. This solution contains 1000 mg/l inorganic carbon.
5. Oxygen Gas, CO_2-free.

D.7.1.4 Procedure

The samples collected in 0.1 N NaOH often contained too much inorganic carbon to allow repeatable determinations, and, therefore, a pretreatment step was necessary. The samples were acidified with concentrated HCl to a pH of 2. The acidified sample was warmed at 50°C (120°F) in a water bath for 10 minutes. The sample was withdrawn from the beaker by means of a hypodermic needle, 20 to 50 μl were injected into the total carbon port of the analyzer and the peak height was measured. The procedure was repeated until three consecutive peaks were obtained with reproducibility of ± 10 percent. Total carbon was determined for a number of samples and then the procedure was repeated using the inorganic channel of the analyzer.

Standard carbon solutions in the range of expected sample concentration were injected, and peak heights of these standards and dilution water blank were recorded. Peak height was corrected for the blank value.

The carbon concentrations of the standards in milligrams per liter were plotted against the corrected peak height in millimeters on rectangular coordinate paper.

The sample concentrations were determined from the corrected peak heights of the samples by reference to this calibration curve.

D.7.1.5 Calculation

The corrected peak height in millimeters (mm) was calculated by deducting the blank correction in the standards and samples as follows:

$$\text{Corrected Peak Height, mm} = A - B$$

where: A = peak height in mm of the standards or sample

B = peak height in mm of the blank

An appropriate dilution factor was applied when necessary.

D.7.2 Phenols - Direct Photometric Method

D.7.2.1 Principle

Phenol and other phenolic compounds react with 4-aminoantipyrine at a pH of 10.0 ± 0.2 in the presence of potassium ferricyanide to form a colored antipyrine dye. This dye is kept in an aqueous solution and the absorbance is measured at 510 nm.

The method requires initial pH greater than 12 (that of 0.1 N NaOH) so front half water washes are either diluted 1+1 with 0.1 N NaOH or basified with a small amount of 10 N NaOH.

The minimum detectable concentration of the method is 0.1 mg/l in an undiluted sample. The detectable concentration varies due to sample turbidity, dilutions, other interfering colors, and reagent inhibitors.

D.7.2.2 Equipment

1. Photometric Equipment

   One of the following, equipped with absorption cells providing light paths of 1 to 5 cm, is required:

   - Spectrophotometer - for use at 510 nm.
   - Filter Photometer - equipped with a green filter exhibiting maximum light transmittance near 510 nm.

2. pH Meter

D.7.2.3 Reagents

Prepare all reagents with distilled water free of phenols and chlorine.

1. Stock Phenol Solution

   Dissolve 1.00 g phenol in freshly boiled and cooled distilled water and dilute to 1,000 ml. Ordinarily this direct weighing of the phenol yields a standard solution. Freshly made 0.1 N NaOH solution may be used to dilute the solid phenol, and thus the stock solution is similar to the samples. The stock is refrigerated to extend the useful life.

   However, if more accuracy than used in this method is required, standardize as follows:

   - To 100 ml distilled water in a 500-ml glass-stoppered conical flask, add 50.0 ml stock phenol solution and 10.0 ml 0.1 N bromate-bromide solution. Immediately add 5 ml concentrated

HCl and swirl the stoppered flask gently. If the brown color of free bromine does not persist, add 10.0-ml portions of bromate-bromide solution until the color does persist. Keep the flask stoppered and let stand for 10 minutes; then add approximately 1 g potassium iodide (KI). Usually four 10-ml portions of bromate-bromide solution are required if the stock phenol solution contains 1,000 mg/l phenol.

- Prepare a blank in exactly the same manner, using distilled water and 10.0 ml 0.1 N bromate-bromide solution. Titrate the blank and sample with the 0.025 N sodium thiosulfate titrant, using starch solution as the indicator.
- Calculate the concentration of the phenol solution as follows:

$$\text{mg/l phenol} = 7.842\ (AB-C)$$

where: A = ml thiosulfate for blank

B = ml bromate-bromide solution used for sample divided by 10

C = ml thiosulfate used for sample

2. Standard Solution

Pipette 5 ml of the 1,000 ppm stock into a 100 ml volumetric flask and dilute to the mark with 0.1 N NaOH. The resulting solution will contain .05 mg/l phenol.

3. Hydrochloric Acid, Concentrated
4. 6 N Hydrochloric Acid
5. Ammonium Chloride Solution

Dissolve 50 g NH_4Cl in distilled water and dilute to 1,000 ml.

6. Aminoantipyrine Solution

Dissolve 2.0 g 4-aminoantipyrine in distilled water and dilute to 100 ml. Prepare a fresh solution on each day of use.

7. Potassium Ferricyanide Solution

Dissolve 8.0 g $K_3Fe(CN)_6$ in distilled water and dilute to 100 ml. Filter if necessary. Prepare fresh each week.

D.7.2.4 Procedure

Exactly 50 ml of sample or suitably diluted aliquot were placed in a 250 ml beaker. The concentration was kept in the range of 0.1 ppm to 5 ppm which corresponds to 0.05 mg to 2.5 mg in a 50 ml sample. Exactly 1 ml of the NH_4Cl solution was pipetted and the pH adjusted using the pH meter to pH 10 ± .2 by adding the 6 N HCl dropwise. 1 ml of aminoantipyrine solution and 1 ml potassium ferricyanide solution were added to the solution; and the solution was mixed well after each addition. After a 15-minute wait, the solutions were read by using a 1 cm cell and/or cuvette at 510 nm in a filter photometer or spectrophotometer.

A complete set of standard solution and a blank were made up each day in the 0.5 ppm to 5 ppm range by suitable dilution of the working standard solution brought to 50 ml with 0.1 N NaOH.

D.7.2.5 Calculations

The sample concentrations were calculated using a linear regression of absorbance versus standard concentration. Alternatively, absorbance and sample concentrations may be plotted on linear graph paper, and sample concentrations determined by comparing sample absorbance to the plotted absorbance values and corresponding concentrations. This concentration was corrected by a factor for any diluted samples; i.e., 1+9 dilution was multiplied by 10. A typical calibration curve is shown in Figure D.1.

D.7.2.6 Quality Control

Standards were run daily, with freshly made up standard solution, to ensure linearity as well as proper spectrophotometer performance. Using linear regression, the daily correlation coefficient, slope and y-intercept were noted.

In addition, a number of samples were duplicated and spiked with a known concentration of standard solution, which insure no interferences in the sample matrix. Half of these quality control samples were run as spikes and the other half as duplicated samples.

Calculated recoveries were determined from the following equation where the calculated spiked sample concentration = A, the unspiked sample concentration = B, the spike value = SV, the known value = KV.

$$A-B = SV$$

$$\frac{SV}{KV} \times 100 = \text{Percent Recovery}$$

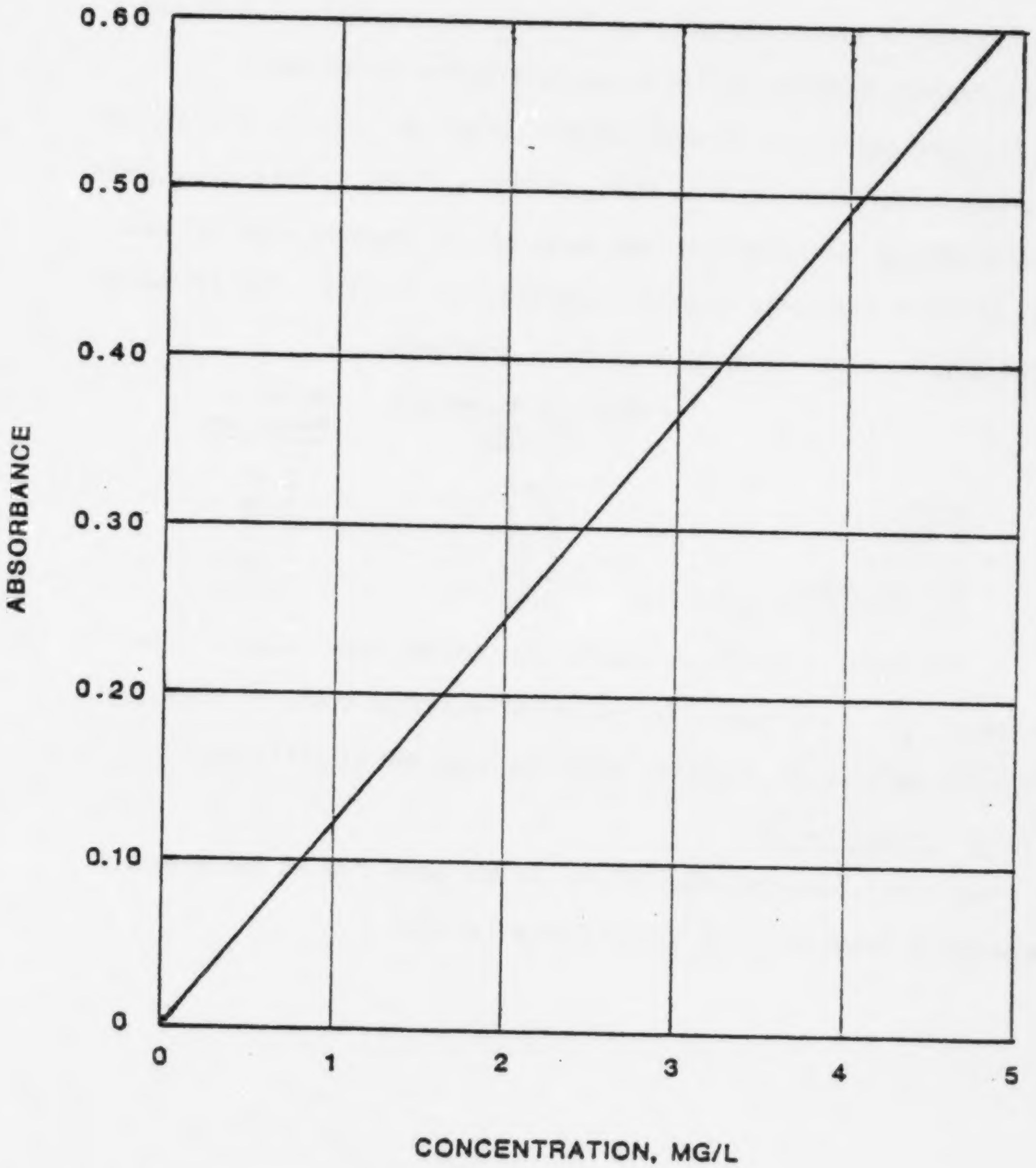
D.7.2.7 Precision and Accuracy

The precision of this method depends on the skill of the analyst and on the interferences present. Because the "phenol" value is based on C_6H_5OH, this method can be regarded only as an approximation and as representing the minimum amount of phenols present. Because the result varies with the types of phenols present.

Figure D-1.

TYPICAL PHENOL CALIBRATION CURVE

(1 cm cuvettes)



D.7.3 Phenol - Gas Liquid Chromatographic Method

D.7.3.1 Principle

This method describes a direct aqueous injection procedure for gas liquid chromatographic analysis of phenol and substituted phenolic compounds collected in 0.1 N NaOH. The method is intended to quantify the concentration of phenol (C_6H_5OH) relative to the concentration of phenolic compounds measured by the 4-aminoantipyrine technique.

A single gas liquid chromatographic column was used to separate phenolic compounds which was then measured with a flame ionization detector. The area of the resulting peak was measured and compared with the peak areas of known standards to obtain quantitative results. The following is the elution order of typical phenolic compounds:

	Absolute Retention Minutes	Relative Retention
phenol	1.67	0.54
o-cresol	2.13	0.69
p-cresol	2.23	0.72
p-ethylphenol	3.09	1.00
2,3 dimethylphenol	3.43	1.11

Differences in operating conditions, column type, support size, treatment, etc., may modify the relative retention times of these compounds as well as the absolute retention time and sensitivity.

D.7.3.2 Interferences

Any other compound which elutes at the same time as the phenolic compound of interest is an interference (ghost).

D.7.3.3 Equipment

1. Gas Chromatograph

   A Hewlett-Packard 5830A chromatograph with hydrogen-flame ionization detector was used. This model is equipped with an integrator/plotter/microprocessor which controls chromatograph operation parameters, electronically monitors and evaluates the detector output, plots the chromatogram, and calculates areas of observed peaks.

2. Column

   Two types of column packings were used for these analyses. Six-foot long by 2 mm ID glass columns containing 80/100 Tenax® or 0.1 percent SP-1000 on Carbopack C were used. The Tenax® column does not separate some of the substituted phenolic compounds but eliminates some of the ghosting problems found with the SP-1000.

3. Syringe

   A 10 1 syringe was used as minimum injection volume was needed to lengthen column life.

4. Reagents

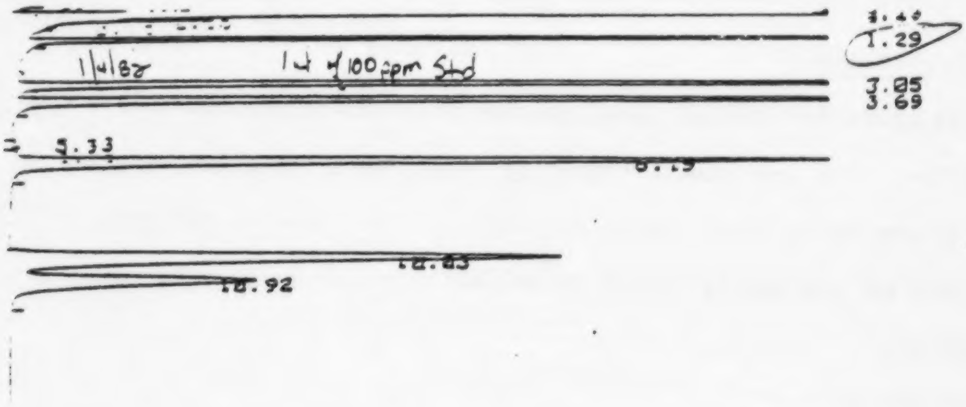
   High purity nitrogen was used as the carrier gas. High purity hydrogen and hydrocarbon-free air were used for the flame. Reagent grade phenolic compounds of the type expected were prepared at 10 to 100 mg/l in redistilled deionized water. Typical compounds are o-cresol, p-cresol, p-ethylphenol, and other substituted phenols. As the analysis was performed to quantify phenol, the substituted phenolics were used to check retention time and detector response.

5. Procedure

The column is installed on the oven and all gas lines connected. The system is leak-checked according to the operation manual for the unit. The column is preconditioned for 24 hours at the operating temperature. The following is a list of typical operating parameters:

- Flow Rates:	Nitrogen - 15 to 20 ml/min
	Hydrogen - 30 ml/min
	Air rate - 250 ml/min
- Temperature:	Injection temperature - 225°C (435°F)
	Column temperature - 225°C (435°F)
	FID temperature - 250°C (480°f)
- Integration/Plotter Settings (HP 18850A Terminal):	Area reject - 100
	Slope sensitivity - 0.10
	Attenuation - 2^4 or 2^5

The area reject value determines the minimum area for which processor reports a peak area. The slope sensitivity is used to determine start and end points of peaks. A typical standard chromatogram and resulting report printout follows as Figure D.2.



```
 0.17      [illegible]    [illegible]
 0.23      [illegible]    [illegible]
 0.29      [illegible]    [illegible]
 0.37      [illegible]    [illegible]
 0.55      [illegible]    [illegible]
 0.75      [illegible]    [illegible]
 1.29        32670          13.481
 3.05        32920          13.584
 3.69        32060          13.229
 5.33      [illegible]    [illegible]
 5.76      [illegible]    [illegible]
 6.19        32440          13.386
10.83        32230          13.299
10.92        16010           6.606
```

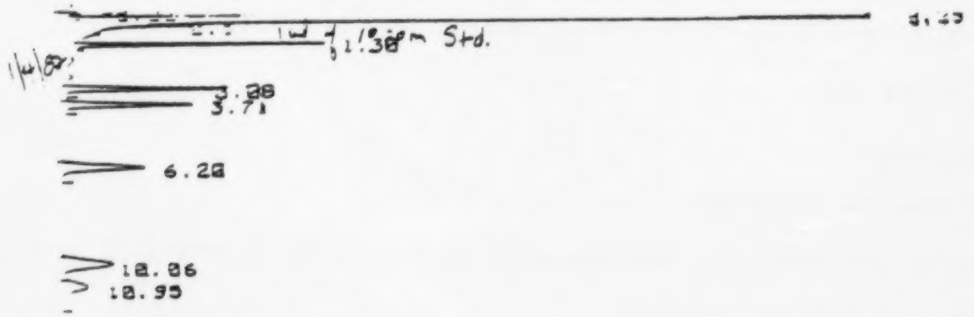


Figure D-2. Typical standard chromatogram.

```
[illegible]  [illegible]   [illegible]
[illegible]  [illegible]   [illegible]
[illegible]  [illegible]   [illegible]
[illegible]  [illegible]   [illegible]
[illegible]  [illegible]   [illegible]
[illegible]  [illegible]   [illegible]
 1.38          3139          4.682*
 3.28          3062          4.567*
 3.71          2966          4.424*
 6.28          3123          4.658*
10.86          3044          4.548*
10.95          1750          2.610
```

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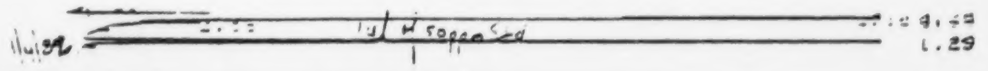


D.7.3.4 Calculations

The area count for a known concentration of standard yielded a calibration factor. The area counts resulting from sample injection were multiplied by the calibration factor to yield a liquid sample concentration. If standard and sample injection volumes are different, a correction was applied.

D.7.4 Formaldehyde

D.7.4.1 Principle

The phenylhydrazone of formaldehyde yields a red color after adding potassium ferricyanide. This reaction is characteristic for formaldehyde and is not disturbed by other homologous aldehydes. Acidification of the samples before analyses removes the possible phenol interferences encountered in the fiberglass plant emissions.

The practical range of the analysis is in the 0 to 12 mg/l range. Depending on the color and the clarity of the sample, a detection limit of 1 mg/l can be achieved using a 15 ml aliquot of sample. The detection limit will be altered by dirty or highly colored samples, which must be diluted to be analyzed.

D.7.4.2 Apparatus

Photometric Equipment

One of the following, equipped with absorption cells providing paths of 1 cm is required:

- Spectrophotometer - for use at 515 nm.
- Filter photometer - equipped with an appropriate filter exhibiting maximum light transmittance near 510 nm.

D.7.4.3 Reagents

Prepare all standards and reagents with an organic-free grade of distilled H_2O.

1. Stock Formaldehyde (CH_2O) ·

   Using freshly distilled H_2O, make up a 0.1 N NaOH solution approximately 2 liters or more for use in making up the standard dilutions. Carefully pipette 1 ml of a 40 percent (326 g/l) formaldehyde solution into a 1 liter volumetric flask 1/2 full of 0.1 N NaOH. Fill to the mark with the 0.1 N NaOH and store in an air-tight glass bottle under refrigeration. This solution contains 326 mg/l CH_2O.

2. Standard Solution

   Pipette 10 ml of the stock solution in 90 ml of 0.1 N NaOH for a standard with a 30 mg/l concentration. This is the working standard. One ml of this solution in a 15 ml aliquot will increase the concentration by 2 mg/l.

3. Hydrochloric Acid, Concentrated

4. 6 N Hydrochloric Acid

5. 5 Percent Potassium Ferricyanide

   Dissolve 5 g reagent grade $K_3Fe(CN)_6$ into 100 ml distilled H_2O.

6. 1.4 Percent Phenylhydrazine Hydrochloride

   Add to 80 ml distilled H_2O, 1.4 phenylhydrazine hydrochloride and 2 ml concentrated HCl. Dilute to 100 ml and filter if necessary. The solution should only have a very faint color. If it is dark colored, a new solution must be prepared.

D.7.4.4 Procedure

To 15 ml of sample in a 50 ml Erlenmyer flask, 1 ml 6 N HCl was added, mixed well, and allowed to stand for about 2 minutes. One ml of 5 percent potassium ferricyanide solution was added and mixed well. Four ml of concentrated HCl and then 2 ml of 1.4% phenylhydrazine solution were added to this solution; the solution was mixed after each addition. The solutions were allowed to stand for 15 minutes before reading absorbance at 515 nm. The color has been shown to be stable for at least one hour after reagent addition.

A complete set of standards were run, in the 0 to 12 mg/l range, daily by dilution of the 30 mg/l standard solution. A typical calibration curve is shown in Figure D.3.

D.7.4.5 Calculations

Same as phenol.

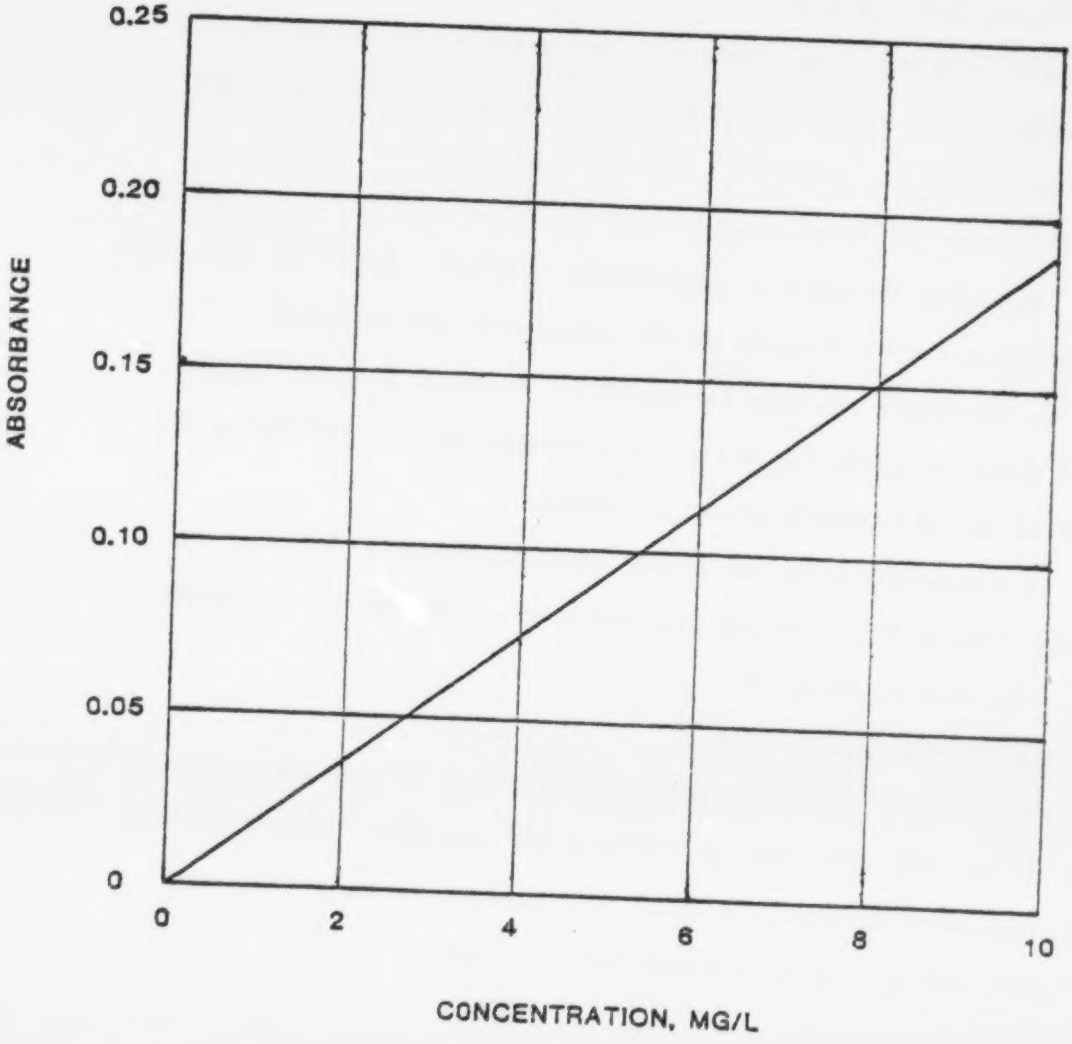
D.7.4.6 Quality Control

Same as phenol.

Figure D-3.

TYPICAL FORMALDEHYDE CALIBRATION CURVE

(1 cm cuvettes)



D.8 CONTINUOUS MONITORING

Many new source performance standards for particulate require transmissometer opacity monitors for assuring proper operation and maintenance of control devices. Transmissometer measurements are not necessarily representative of opacity or mass emissions from the exhausts of wool fiberglass plants and, therefore, continuous opacity monitors are not recommended for this source. The effects of variable stack gas temperature can cause the readings of the transmissometer to lack any correlation with Reference Method 9 measurements. For example, by increasing the stack temperature, the condensible particulate matter that cause the visible emissions may exist as a gas which would not be detected by the transmissometer but which could recondense and be visible in the atmosphere. Reference Method 9 is recommended on a daily basis for monitoring the operation and maintenance of the process control equipment except where wet scrubbers are used for control. Pressure drop and scrubber liquid flow rate measuring devices are recommended for monitoring the operation and maintenance of wet scrubbers.

The annualized costs for either periodic Method 9 readings, or scrubber liquid flow rate and pressure drop monitoring are estimated to be less than $2,500/year.

D.9 PERFORMANCE TEST METHODS

Performance Test Method 5E[6] is recommended for the measurement of particulate emissions from wool fiberglass processes. Method 5E is a modification of Reference Method 5 with changes in the cleanup and analyses, and the use of the back half impingers.

The Method 5E sampling train is a standard Method 5 probe and filter followed by four Smith-Greenberg type impingers. The first two impingers are filled with 100 ml each of 0.1 N NaOH. The third impinger is empty and the fourth impinger is filled with silica gel for moisture determination. The filter temperature is maintained at 120°C ± 14°C (248°F ± 25°F). Train cleanup differs from Method 5, in that the probe and nozzle are rinsed three times, without brushing, with distilled water before the acetone rinsing and brushing step, and the impingers are rinsed with 0.1 N NaOH after transferring the contents to a container for a later total organic carbon (TOC) analysis.

TOC analysis is performed by injecting pretreated aliquots of back half sample into a Beckman type TOC analyzer, and the difference between the peak height between the total carbon and inorganic carbon is the concentration of the total organic carbon in the back half impinger solution.

Particulate analyses of the front half of the sampling train consists of a separate dry down for the water rinse and a dry down of the acetone rinse and filter. These separate dry down concentrations are added together for a total front half concentration.

Sampling costs for a test consisting of three Method 5E runs is estimated to be about $10,000 to $14,000. If in-plant personnel are used to conduct the tests, the costs will be somewhat less.

Method 9 is recommended for measurement of opacity from stacks, except from scrubber exhaust stacks where condensible particulate matter combined with water droplets can cause interference with an opacity determination.

D.10 REFERENCES FOR APPENDIX D

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2. Method Development and Testing for the Fiberglass Industry - Final Method Development Report. Engineering Science Report for USEPA, Office of Air Quality Planning and Standards, ESED, EMB, Research Triangle Park, NC 27711. EPA Contract No. 68-02-3541. McLean, Virginia. April 1981. 35 pp. plus Appendices.
3. NIOSH Manual of Analytical Methods. U.S. Department of Health, Education and Welfare, National Institute for Occupational Safety and Health. NIOSH Publication No. 75-121. Cincinnati, Ohio. 1974. p. 125-1 to 125-9.
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APPENDIX E. ADDITIONAL INFORMATION ON DEMAND AND PRICE DETERMINATION FOR WOOL FIBERGLASS

This technical appendix contains additional information on demand and price determination for wool fiberglass.

E.1 DEMAND DETERMINANTS

The purposes of this discussion are: (1) to summarize the choice of each of the determinants of demand, (2) to provide the results of the empirical estimates of demand, and (3) to summarize the results of an alternative approach to estimating demand, namely, the use of technical coefficients.

E.1.1 Determinants of Demand

The logic for including each of the demand determinants in Section 9.1.3.6 is discussed here.

E.1.1.1 Price of Wool Fiberglass In standard economic analysis, the demand for an input (in this case wool fiberglass insulation) is negatively related to its own price. One of the factors that must be held constant is the price of all other substitutes and complements for wool fiberglass.

In practice, keeping all other prices constant means that the price of wool fiberglass must be deflated by either an economy-wide measure of all prices (such as the wholesale price index) or by an industry-specific measure for the cost of all inputs into the end product of the user industries (here, construction). The choice made in this study is to use the composite cost index of all inputs into the construction industry as a deflator. This choice is justifiable on empirical grounds; if the construction industry has a constant elasticity of substitution (CES) production function, it also becomes the preferred theoretical choice.

Table 9-9 tracks the behavior of the price of wool fiberglass relative to the total cost of construction. As the numbers in the table show, the deflated price of wool fiberglass has fallen in most years since 1965 (exceptions are 1975, 1980 and 1981). Demand is negatively related to the price term. The correlation between the two variables is high (r=0.8934).

E.1.1.2 Output in User Industries. Table 9-4 provides estimates of the demand for wool fiberglass by end-use in 1980. From this table, one can see that 79 percent of demand was used for the thermal insulation of residential and nonresidential structures. New houses and the retrofit market together accounted for almost 58 percent of the total demand for insulation in 1980.

Table 9-9 summarized the historical behavior of output in various user industries. Between 1965 and 1981, output in these industries has grown, suggesting that the demand for wool fiberglass has increased. Data on housing starts and the retrofit market are reviewed here since they have been the major determinants of demand in recent years.

Housing starts are directly related to the state of the economy as a whole and to prevailing interest rates. In 1980, housing starts were lower than at any time since 1966. Preliminary estimates for 1981 are 1.103 million units compared with the 1980 figure of 1.313 million units.[1] This is primarily the result of the high interest rates that have existed in recent years. The effective rate on conventional mortgages in 1980 was 12.7 percent. The effective rate rose to 14.7 percent in 1981.[2] The monthly cost of purchasing and financing a new home has become so high that many home buyers have been priced out of the market. Therefore, there are relatively few housing starts compared with the past.

Historically, the demand for wool fiberglass has been positively related to the number of new housing starts. The correlation between the two variables over the period 1962 to 1980 is low (r = 0.3620). The major explanation for the low correlation between housing starts and demand is the retrofit market, which has dominated the wool fiberglass insulation industry since the oil embargo in 1974.[3]

There are various estimates of the size of the retrofit market as Table E-1 makes clear. The Frost and Sullivan estimates have been used in this analysis because they provide a consistent set of estimates over the historical and forecast periods.

TABLE E-1. ESTIMATES OF THE SIZE OF THE RETROFIT MARKET, 1970 TO 1991[3-6] (10^6 units)

Year	Williams	Owens-Corning	Goldfarb	Frost and Sullivan	JACA[a]
1970	-	-	-	0.5	0.5
1971	-	-	-	0.5	0.5
1972	-	-	-	0.5	0.5
1973	-	-	-	1.0	1.0
1974	2.7	2.0	-	2.5	2.5
1975	2.7	2.5	-	2.6	2.6
1976	2.7	2.0	-	3.0	3.0
1977	7.0	6.0	-	6.0	6.0
1978	5.4	4.9	-	4.5	4.5
1979	6.2	5.7	-	5.0	5.0
1980	3.4	5.0	3.4	4.5	4.5
1981[b]	-	5.4	3.3	-	4.1
1982[b]	-	-	3.4	3.8	3.8
1983[b]	-	-	3.45	-	3.5
1984[b]	-	-	3.45	-	3.2
1985[b]	-	-	-	2.9	2.9
1986[b]	-	-	-	-	2.9
1987[b]	-	-	-	-	2.8
1988[b]	-	-	-	-	2.8
1989[b]	-	-	-	-	2.7
1990[b]	-	-	-	2.7	2.7
1991[b]	-	-	-	-	2.7

[a] JACA estimates are the Frost and Sullivan series, with linear interpolations between forecast years; the 1991 retrofit market is assumed to be the size of the 1990 market.

[b] Forecasts.

The retrofit market has always existed but it became significant following the 1974 oil embargo.[3] In recent years it has dominated the wool fiberglass insulation market because of the currently depressed housing market. The tendency to retrofit insulation to existing residential structures has been reinforced by the income tax credit for energy conservation, a law which became effective in 1977. The correlation coefficient between the output of wool fiberglass and the retrofit market between 1962 and 1980 is 0.9114.

E.1.1.3 Changing Technical Coefficients. In recent years, changes in two technical coefficients have increased the input-output (I-O) coefficient for wool fiberglass. These technical coefficients are: (1) the percent of residential construction using fiberglass rather than its substitutes as an insulation material, and (2) the amount of total insulation used per unit of new and retrofitted residential structures. Demand estimates for the residential market are presented in Table E-2.

The changes in those coefficients are, in turn, due to the operation of two different price mechanisms. For example, the increasing amount of total insulation used per unit of each type of residential structure is due to the increasing costs of energy. Specifically, the unit weight of insulation used per unit of output is negatively related to the ratio of the price of insulation to the price of fuels for heating purposes. In residential structures, for example, attic insulation increased from 2 inches in the fifties, to 4 inches in the sixties and to 6 inches in the early seventies.[7] A formal test of the relationship between energy prices and pounds of insulation used cannot be made because of the lack of complete input-output (I-O) data and because of the lack of historical data on the prices of insulation materials except wool fiberglass and cellulose.[8,9] The increase in the percentage of wool fiberglass used per unit of output may in part be due to decreases in the price of wool fiberglass relative to the price of its substitutes and to quality factors that cannot be quantitatively measured.

In the absence of data that allow the analyst directly to estimate each technical coefficient, a time trend can be utilized to capture the increasing I-O coefficients for wool fiberglass. This proxy has the

TABLE E-2. ESTIMATES OF THE DEMAND FOR WOOL FIBERGLASS FOR THERMAL INSULATION OF RESIDENTIAL STRUCTURES USING TECHNICAL COEFFICIENTS[1,5,10-12]

	New residential construction except mobile homes					
	Housing starts (10^6 units)	Use of fiber-glass (%)	Insulation per unit		Total demand for fiber-glass in new housing[a]	
Year			(Kg)	(lb)	(Gg)	(10^6 lb)
1970	1.469	52.7	193	425	149	329.0
1971	2.085	59.7	213	470	265	584.0
1972	2.379	54.6	234	515	304	669.0
1973	2.058	55.6	259	570	296	652.2
1974	1.353	48.4	283	625	186	409.3
1975	1.171	53.3	297	655	186	408.8
1976	1.548	53.4	313	690	259	570.4
1977	2.002	48.6	348	768	339	747.2
1978	2.036	60.6	353	778	436	959.9
1979	1.760	61.8	376	830	410	902.8
1980	1.313	64.4	408	900	345	761.0

New construction of mobile homes					
Shipments in mobile homes (10^6 units)	Use of fiber-glass- (%)	Insulation per unit		Total demand for fiber-glass in mobile homes[b]	
		(Kg)	(lb)	(Gg)	(10^6 lb)
0.401	87.5	NA[c]	NA[c]	NA[c]	NA[c]
0.497	87.5	NA	NA	NA	NA
0.576	87.5	NA	NA	NA	NA
0.567	87.5	NA	NA	NA	NA
0.329	87.5	NA	NA	NA	NA
0.213	87.5	NA	NA	NA	NA
0.246	87.5	NA	NA	NA	NA
0.277	87.5	NA	NA	NA	NA
0.276	87.5	NA	NA	NA	NA
0.277	87.5	NA	NA	NA	NA
0.222	87.5	48	246	48	105.5

(Continued)

TABLE E-2, continued

	Retrofit of existing houses						Total demand for wool fiberglass for thermal insulation of residential structures[e]	
	Number of homes retrofitted with insulation	Use of fiberglass	Insulation per unit		Total demand for fiberglass in retrofitted market[d]			
	(10^6 units)	(%)	(Kg)	(lb)	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)
1970	0.5	NA	64	142	NA[c]	NA[c]	NA[c]	NA[c]
1971	0.5	NA	71	157	NA	NA	NA	NA
1972	0.5	NA	78	172	NA	NA	NA	NA
1973	1.0	NA	86	190	NA	NA	NA	NA
1974	2.5	NA	94	208	NA	NA	NA	NA
1975	2.6	NA	99	218	NA	NA	NA	NA
1976	3.0	NA	104	230	NA	NA	NA	NA
1977	6.0	NA	109	240	NA	NA	NA	NA
1978	4.5	NA	113	250	NA	NA	NA	NA
1979	5.0	NA	116	255	NA	NA	NA	NA
1980	4.5	72.0	119	119	387	852.1	780	1,718.6

[a] Housing starts times percent using fiberglass times insulation per unit.

[b] Shipments of mobile homes times percent using fiberglass times insulation per unit.

[c] NA = not available.

[d] Number of homes to be retrofitted times percent using fiberglass times insulation per unit.

[e] Demand for fiberglass in new housing plus demand for fiberglass in mobile homes plus demand for fiberglass in the retrofit market.

advantage of capturing changing I-O coefficients not only in residential structural insulation but also those, if any, in nonresidential structural insulation and in non-structural insulation. The latter is not available in either Goldfarb or Frost and Sullivan, both of which utilize technical coefficients to forecast residential demand.[5, 6, 13]

E.1.2 Empirical Demand Estimates

The demand for wool fiberglass from 1962 to 1980 can be estimated from the following equations:

$$XWF = A\,(PIWF/PIC)^{\alpha}\,(XHS)^{\beta}\,(XNRC)^{\gamma}\,(XRET)^{\delta}\,e^{\rho T}\,e^{u} \qquad \text{(Eq. E-1)}$$

$$\beta + \gamma + \delta = 1 \qquad \text{(Eq. E-2)}$$

where XWF = the output of wool fiberglass in millions of pounds
PIWF = the price index of wool fiberglass (1967 = 100)
PIC = the price index of the cost of construction (1967 = 100)
XHS = the number of housing starts, in millions of units
XNRC = the value of new nonresidential construction put in place, in millions of 1972 dollars
XRET = the number of homes retrofitted, in millions of units
T = a time trend
$A, \alpha, \beta, \gamma, \delta$, and ρ = parameters to be estimated
e = the natural logarithm = 2.718
u = the error term

The imposition of the restriction that the sum of the elasticities on output equals 1 (Eq. E-2) has the major advantage of forcing the equation to have the desirable long-run property that a 1 percent rise in the total output of the user-industries, other things being equal, causes a 1 percent rise in the demand for wool fiberglass. The changing technical or input-output coefficients in the use of wool fiberglass over time are then captured in the trend term, T.

The results of the empirical estimate of the equivalent equation in natural logarithms are:[14]

$$[\ln(XWF) - \ln(XRET)] = \underset{(15.13)}{2.1102} - \underset{(4.95)}{0.5667} \ln(PIWF/PIC) + \underset{(7.87)}{0.3283} [\ln(XHS) -$$

$$\ln(XRET)] + \underset{(11.47)}{0.5134} [\ln(XNRC) - \ln(XRET)] + \underset{(8.98)}{0.0288} (T) \qquad \text{(Eq. E-3)}$$

$\overline{R}^2 = 0.9983$

$F = 2038.68$

$SSE = 0.0140$

$DW = 2.04$

PERIOD = 1962 to 1980

The numbers in parentheses in the equation are the t-statistics; each variable is significant at the 1 percent level. Given the F-statistic, the overall explanatory value of the equation is significant at the one percent level as well. The differences between actual and predicted values are present in Table E-3.

Elasticities are presented in Table 9-10. For example, the own-price elasticity of demand of -0.5667 means that a 1 percent increase in price will lead to a 0.57 percent decrease in demand. Similarly, a 1 percent increase in the number of new housing starts will lead to a 0.33 percent increase in the total demand for wool fiberglass. If output in all three user industries increases 1 percent, the demand for wool fiberglass will increase 1 percent because of the restriction imposed on the user industry output variables.

E.1.3 Other Empirical Estimates

There is an alternative to the econometric approach that has frequently been used to explain the sources of changes in the demand for wool fiberglass. This alternative combines user-industry output and technical coefficients to estimate the demand for wool fiberglass for residential structures with ad hoc techniques to estimate all other demand. This approach, which we call "technical coefficients/ad hoc," has been used both by Goldfarb and also by Frost and Sullivan.[5,13] For those forecasts that use technical coefficients, Goldfarb forecasts the number of housing starts, which is multiplied by the estimate of the number of pounds of wool fiberglass used in a typical house to obtain total wool fiberglass

TABLE E-3. ACTUAL VERSUS PREDICTED VALUES OF WOOL FIBERGLASS OUTPUT, 1962 TO 1980[a]

Year	Actual		Predicted	
	Gg	10^6 lb	Gg	10^6 lb
1962	396	873.2	404	890.1
1963	441	971.6	440	968.2
1964	426	938.2	430	947.7
1965	475	1,045.7	469	1,033.9
1966	488	1,075.6	448	986.8
1967	471	1,037.5	478	1,053.9
1968	510	1,124.3	530	1,167.0
1969	546	1,202.7	546	1,202.2
1970	539	1,186.3	561	1,236.2
1971	689	1,517.2	694	1,529.2
1972	800	1,761.9	770	1,696.3
1973	880	1,939.0	882	1,942.5
1974	893	1,967.5	893	1,967.6
1975	777	1,711.9	794	1,748.6
1976	942	2,074.0	920	2,026.6
1977	1,165	2,565.7	1,158	2,550.8
1978	1,232	2,714.4	1,227	2,703.9
1979	1,296	2,854.7	1,315	2,896.1
1980	1,190	2,622.1	1,176	2,590.1

[a] Equation E-3 in text and Table 9-3.

usage. In the case of forecasts that use ad hoc techniques (pipes, equipment, and so forth), Goldfarb does not explain what techniques he uses to arrive at his projections.

Table E-4 reproduces Goldfarb's use of technical coefficients and ad hoc techniques to estimate 1980 demand and to forecast demand to 1984.

The technical coefficient approach has the advantage of spelling out in detail the assumptions that an analyst makes about several factors for which product equals demand in a given market, for example, new houses. These factors are: the number of housing starts, the percent using fiberglass, and the unit weight of insulation per unit.

The technical coefficient/ad hoc approach has, however, several disadvantages. One, there is no explicit role for the price of wool fiberglass, yet the estimate of prices has a bearing on demand (unless price elasticity is zero). The impact of assumptions about prices on demand are shown in Section 9.3.4, where alternative assumptions about future prices lead to different projections of demand growth from 1980 to 1991. Two, ad hoc projections for both the nonresidential structural market and the total nonstructural market are unsatisfactory. It is impossible to determine the origin of the projections and, therefore, impossible to devise a method to test their validity, yet these two markets accounted for 37.6 percent of the total demand for wool fiberglass in 1980.

E.2 PRICE DETERMINANTS

The purposes of this discussion are: (1) to summarize the logic of the choice of each of the determinants of price, and (2) to provide the results of the attempts to estimate empirical price equations.

E.2.1 Determinants of Price

The logic for including each of the determinants of price in Section 9.1.3.8 is discussed here.

E.2.1.1 Materials Price. The major inputs into wool fiberglass insulation are the raw materials for glass, the phenolic resin binder, and energy, chiefly natural gas and electricity.[15] The materials are generally abundant and are readily available. The raw materials used for the glass in the wool fiberglass industry are silica, feldspar, salt cake (sodium sulfate), soda ash (sodium carbonate), fluorspar, cryolite, and borax. Although there have occasionally been spot shortages of soda ash, they

TABLE E-4. GOLDFARB FORECASTS OF TOTAL DEMAND FOR WOOL FIBERGLASS, 1980 TO 1984, USING TECHNICAL COEFFICIENTS AND AD HOC METHODS[5] (10^6 lb)

Year	Thermal insulation of structures			Thermal insulation of pipes, equipment, and other high-density uses				Total demand	
	Residential[a]	Nonresidential[b]	Total[c]	Pipes[d]	Handling[e]	Other[f]	Total[g]	Level of demand[h]	Percent change
1980	1,621	435	2,056	175	130	235	540	2,596	-
1981[i]	1,581	414	1,995	190	140	235	565	2,560	-1.4
1982[i]	1,842	388	2,230	200	150	245	595	2,825	10.4
1983[i]	2,165	435	2,600	220	170	270	660	3,260	15.4
1984[i]	2,318	492	2,810	245	195	295	735	3,545	8.7

[a] Goldfarb largely uses technical coefficients to forecast demand for three residential end-uses: housing starts, mobile home shipments, and the residential retrofit market. Demand for wool fiberglass in housing starts is the number of housing starts times the average pounds of wool fiberglass per housing start. Demand for wool fiberglass in mobile homes is the number of units shipped times the pounds per unit of mobile homes. The retrofit market is the number of homes being retrofitted times the percent using fiberglass times pounds per unit.

[b] Nonresidential insulation is the sum of light-density nonresidential insulation and heavy-density roof insulation for nonresidential structures. These series are aggregated to conform to Census data.

[c] Residential plus nonresidential thermal insulation of structures.

[d] Pipe insulation for both residential and nonresidential structures, both new and retrofit.

[e] Air-handling is rigid fiberglass ductboard (in lieu of galvanized steel).

[f] Includes appliance insulation, ceiling materials, and automotive insulation.

[g] Thermal insulation of pipes plus handling plus other.

[h] Total thermal insulation of structures plus total thermal insulation of pipes, equipment, and other high-density uses.

[i] Forecasts.

have not lasted long. The binder is produced from benzene and methanol and is related to the availability of petrochemical feedstocks. Neither natural gas nor electricity have been in short supply.[16-28]

Table 9-11 shows that unit material costs in the wool fiberglass industry rose at an annual compound rate of only 4.3 percent between 1965 and 1979. There were, however, sharp increases in 1974, 1975, and 1978. These increases were primarily due to escalating energy prices; the price of oil, for example, rose 58 percent in 1974, 8.3 percent in 1975, and 40.4 percent in 1979. (The correlation coefficient between the two variables is 0.9855.)

E.2.1.2 Unit Labor Costs. Table 9-11 shows that unit labor costs can be estimated both for all employees and for production workers. In the case of production workers, unit labor costs can be broken into their two components: the wage rate and productivity. Both types of unit labor costs rose at an annual compound rate of 3.3 to 3.4 percent per year between 1965 and 1979. Wage rates rose at a higher rate of 6.8 percent, but these increases were partially offset by a rise in productivity of 3.4 percent per year.

There are high correlations between prices and total unit labor costs of all employees ($r = 0.9573$) and the unit labor costs of production workers ($r = 0.9385$). Although the sharp increases in prices in 1974 and 1975 were apparently due to increases in material costs, the declines in 1971 and 1972 were apparently due to decreases in unit labor costs.

E.2.1.3 Unit Capital Costs. Data on production capacity are presented in Table E-5. Although these data are incomplete over the historical period, they do show a marked increase in capacity due to new plant construction between 1975 and 1979. This expansion in capacity was a response to the pressure placed on capacity in 1973 and 1974 when the retrofit market became a significant additional market due to the oil embargo and the rapid increase in fuel prices.

The unit capital costs reported in Table 9-11 are the user cost of capital in time t multiplied by the size of assets in time t. Thus:[29]

$$UKC = UCK\,[(A_t)/(XWFU)] = UCK_t\,[(A_{t-1} + I_t)/(XWFU)] \qquad \text{(Eq. E-4)}$$

TABLE E-5. OUTPUT, CAPACITY, AND CAPACITY UTILIZATION, 1970 TO 1980[30-33]

Year	Output[a]		Capacity		Capacity utilization[b]
	(Gg)	(10^6 lb)	(Gg)	(10^6 lb)	(Percent)
1970	538	1,186	NA[c]	NA	NA
1971	689	1,517	NA	NA	NA
1972	800	1,762	NA	NA	NA
1973	880	1,939	908	2,000	96.9
1974	893	1,968	908	2,000	98.3
1975	777	1,712	953	2,100	81.5
1976	942	2,074	1,169	2,575	80.6
1977	1,165	2,566	1,310	2,885	88.9
1978	1,232	2,714	NA	NA	NA
1979	1,296	2,855	1,553	3,420	83.5
1980	1,190	2,622	1,632	3,595	72.9

[a] Output is shipments of wool fiberglass.
[b] Output divided by capacity.
[c] NA=not available.

where UKC = unit capital costs, in dollars per ton

UCK = user cost of capital, a percent

A = assets, in dollars

XWFU = output of wool fiberglass, in tons

I = investment, in dollars

The user cost of capital is a Wharton index, which takes explicit account of the following capital cost terms: the bond rate, depreciation rate, the investment tax credit, the effective corporate tax rate, and tax life.[34]

Unit capital costs rose 11.9 percent between 1965 and 1979. The largest increases were in 1974 and 1975; unit capital costs declined in 1971, 1976, and 1977. With the exception of the period 1976 to 1977, these changes parallel price changes in wool fiberglass. (The correlation coefficient between prices and unit capital costs was 0.9714 between 1965 and 1979.)

E.2.1.4 Demand Pressures. Demand pressures play a diminished role in oligopolies compared with competitive industries because price no longer responds instantaneously, if at all, to the difference between demand and supply. Typical empirical measures of temporary demand-supply disequilibrium are capacity utilization, the ratio of the change in unfilled orders to sales, and, to a lesser extent, the ratio of the change in inventories to sales.[35] Therefore, as one might expect, there is a very weak correlation ($r = 0.1794$) between prices and the ratio of inventories to sales.[35]

E.2.1.5 Pricing Strategies. The dominant theory of oligopoly pricing indicates a target-return, full-cost pricing mechanism, although the range of short-run possibilities lies between the extremes of average variable cost pricing and average total cost pricing.[36,37] The available evidence suggests, however, that oligopolies are unresponsive to short-run demand pressures (so that, as demand rises, more of the market adjustment falls on rationing, backlogs of orders, and drawdowns of inventories) and therefore are highly responsive to increases in "standard" costs.[36] Therefore prices change only if the standard price of inputs changes or if there is technological progress--both of which "permanently" alter unit costs of production.

The available evidence suggests that the wool fiberglass industry sets prices on the basis of standard costs, not demand pressures. In this industry, Owens-Corning is the acknowleged price leader. (When other firms in the industry have increased prices but Owens-Corning has not, the price increases have not prevailed, that is, the other firms have withdrawn their price increases.) Owens-Corning has raised prices when its costs increase but it has not raised prices in response to short-run demand pressures. For example, during the period between late-1977 and early-1979 when wool fiberglass was virtually sold-out and there was a backlog of orders, insulation prices did not increase.[32]

E.2.2 Empirical Price Equations. A formulation of an empirical price equation incorporating the above concepts is:[38]

$$PWFVA = (PWF - UMC) = A\,(ULC)^{\alpha}(UKC)^{\beta}e^{\gamma(\Delta INV/S)}\,e^{u} \qquad \text{(Eq. E-5)}$$

and

$$\alpha + \beta = 1 \qquad \text{(Eq. E-6)}$$

where PWFVA = the value added price of wool fiberglass, in dollars per ton
PWF = the price of wool fiberglass, in dollars per ton
UMC = unit materials costs, in dollars per ton
ULC = unit labor costs, in dollars per ton
UKC = unit capital costs, in dollars per ton
INV = inventories, in dollars
S = sales, in dollars
A, α, β, and γ = the parameters to be estimated
e = the natural logarithm = 2.718
u = the error term.

The imposition of the restriction that changes in materials costs are passed on without a markup is consistent with good theoretical relationships, as well as with empirical evidence.[38] The restriction in Equation E-6 means that, if value added costs rise 1 percent, then prices will rise one percent, other things being equal. The coefficient γ captures the markup on costs, if any, due to demand pressures. Capacity utilization is the preferred variable to capture demand pressures, but it is not available for most of the historical period, hence the use of (ΔINV/S). It should be noted that the mathematical formulation of Eq. E-5 differs from Eq. E-1, because one cannot take the log of zero -- a possibility with the variable (ΔINV/S).

Unfortunately, strong multicollinearity was evident in the price equation. It was not possible to make any feasible adjustments that would retain the theoretical and empirical soundness of the equation.

For purposes of forecasting future growth, an equation in which prices are only a function of a time trend was estimated. The results of this estimation are presented in Section 9.1.4, where the demand for wool fiberglass is forecast to 1991.

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